

**DIVISIBILITY
OF
SILK FIBRE.**

**Sir T. WARDLE,
LEEK.**

AND ALSO
"SULLO SFILACCIARSI
DELLE SETE TINTE,"
Silk Laboratory Researches,
MILAN.

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An Examination into the Divisibility of the Brin or Ultimate Fibre of the Silk of Bombyx Mori, or Silk of Commerce, and of some Wild Silks, with Illustrations.

BY

Sir THOMAS WARDLE, J.P.,

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Throwing and Spinning, and in Silk Dyeing, City and Guilds of
London Institute ; President of the Silk Association of Great Britain
and Ireland ; Hon. Sec. of the Ladies' National Silk Association ;
Founder and Adviser of the Sericicultural Industry of Kashmir.

*Followed by a separate Monograph Sullo Sfilacciarsi delle Sete
Tinte, being the Report of a similar Investigation carried out
under the auspices and in the Laboratory of the Societa
Anonima Co-operativa per la Stagionatura e l'Assaggio
delle Sete ed Affini (Laboratory of Silk Studies), Milan, Italy.*

Translated from the Italian by

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WORKS BY THE AUTHOR.

- The Wild Silks of India.
 Examination of the Dyes and Tans of India for the Government of India.
 Monographie sur l'Industrie des Soies Sauvage et des Matières de Teinture de l'Inde, Exposition Universelle de 1878, Paris.
 On Carboniferous Limestone, its Occurrence, Nature, and Origin.
 Address on Art Culture, Newcastle-under-Lyme.
 Lecture on Silk at the University of Nottingham.
 Report on the English Silk Industry, written for the Royal Commission on Technical Instruction.
 On Several Species of Silk Fibre and on the Silk Industry, Bradford.
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 English Edition of "Cours de la Sericulture Pratique," by Laurent de l'Arbousset, edited by T. Wardle; translated by his daughter, Elizabeth Wardle.
 Kashmir, its new Silk Industry, Geology, Sport, &c.
 Paper on a new Carboniferous Limestone Fern, Butterton, Adiantides Wardlei, Howe.
 Classification of the Animal Kingdom, and the Carboniferous Limestone Fossils of North Staffordshire.
 Classified List of Fossils from the Cambrian, Ordovician, and Silurian Systems.
 Address at Halifax to the Students of the Technical Institute.
 Address to the Students of the Technical School, Bath.
 Address on Art and the Revival of the Silk Industry, at Macclesfield.

I am sorry to find that two names have been inadvertently omitted which should have been included in my mention of the researches conducted by the Milan Laboratory of Silk Studies, namely, Professor Gianoli, President of the Chemical Society, Milan, and his collaborator, Doctor Colombo, of the Laboratory of Silk Studies.

I have to acknowledge with much pleasure the excellent assistance I have received from Miss Kate Milner in translating the Milan Monograph, pages 3 to 47, which forms the second part of this Brochure; to my niece, Miss E. Wardle, for her drawings of the African Cocoons, on pages 75, 79, 83, 87, and of the moth Anaphe Infracta, on page 79: also to Miss Kate Lowe for her revision and correction of proofs.



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AN EXAMINATION INTO THE DIVISIBILITY OF THE BRIN OR ULTIMATE FIBRE OF THE SILK OF BOMBYX MORI, OR SILK OF COMMERCE.

SINCE 1901 I have been more or less continuously investigating the curious phenomenon of a peculiar kind of white speckiness occasionally occurring in both degummed and dyed silk yarns, and also in some textiles.

It will be seen from the Monograph, entitled "*Sullo Sfilacciarsi delle Sete Tinte*," published by the Laboratorio d'Esperienze sulla Seta della Societa Anonima Co-operativa, Milan, which follows mine, that I have not been alone in the researches connected with this curious defect and property of exfoliation or splitting-up of the brin of silk. It has been shared in by Monsieur Testenoire, Director of the Lyons Conditioning House, and others of the staff; also by Signor Corti, of Milan; by Monsieur Lambert, Directeur de l'Ecole Nationale d'Agriculture de Montpellier, Station Sericicole, Montpellier; and Cavaliere Verson, Director, R. Stazione Bacologica, Padua; also Dott. E. Quajat, Assistant Director, R. Stazione Bacologica, Padua; and others.

So far back as 1878 I had succeeded in the laboratory in dividing the single fibre or brin of Indian Tussur silk, *Antheræa mylitta*, and had figured a divided fibre in my Handbook on the "*Wild Silks of India*," published for the Government in 1881, and which I now reproduce (see Plate 12, Fig. C); see also Plate 6 of the following Monograph.

But that was a possibility plainly evidenced by the microscopic appearance of the flattish fibre, which is shown to be ribbed, or internally fibrous, as in Plate 12, Fig. C, an appearance very evident in nearly all the silks of the Saturniidæ family, whilst in the Bombycidæ, or mulberry feeders, no such appearance is visible even with the highest magnifying power, the silks of which have translucent and homogeneous fibres, and more or less round.

As soon as the Monograph of my friends and colleagues appeared I resolved to issue a translation of it, in which I have had the advantage of the assistance of my friend, Miss Kate Milner, which is illustrated by the same process-blocks as those used in the Milan edition, kindly lent to me by Signor Corti for the purpose, but my multifarious engagements prevented my giving the subject immediate attention; and I must compliment my American confrères with having most successfully issued an American translation, and I congratulate them on the excellence both of the illustrated translation and appearance of their Monograph.

I should have contented myself with this translation but for two reasons; first, that it was necessary there should be an English issue within reach of the English dyers, to whom the considerations involved in it are a necessity, and to English manufacturers, neither of whom, dyers and manufacturers, were at all acquainted with the exact nature of the phenomenon treated of, except by the external appearance of speckiness; and, secondly, I desired an opportunity of expressing my own views and researches on the subject.

DIVISIBILITY.

With Dr. Quajat and Messrs. Conte and Levrat, I think I may claim the discovery of the nature and cause of the fibrillæ and fiocchetti, at any-rate in England.

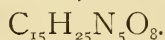
I do not find myself in agreement with Professor Lenticchia, who states, in 1896, that the channelling or fibrous structure of the brin of the Bombyx Mori is owing to extremely thin fibrils of sericin contained in the fibroin (see page 15 of the following translation). If anything of the kind takes place, which I much doubt, I should attribute it to a reversed action, namely, that the channelling or non-fibrous material is due to the sericin, and that the ribbiness is the fibroin, which is insoluble in the soap and dye-baths. He admits that it is possible to

obtain the channelling or fibrillæ of the *Bombyx Mori* by the same means that I discovered the method of obtaining and separating them in the fibres of the *Saturniidæ* in 1880, namely, by the use of permanganate of potash, and credits me with establishing the relation between the channelling and exfoliation of the fibre into fibrillæ. I do not, however, think his inference is correct, namely, that the fibres, which are more apt to exfoliate during the operation of ungumming and dyeing, probably owe their origin to the deleterious action of sulphurous fumes, to which the worms have been exposed during the period of breeding.

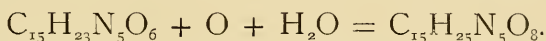
But with regard to both these surmises, we must wait for further investigation in the direction of ascertaining the relative composition of the fibrillæ, and that of the glutinous material which holds and binds them together.

Silk is composed of fibroin—that is, the insoluble part of silk proper—and sericin, which is the cement, or, as it is called, gum in England, and in France grès, a glutinous matter or varnish with which the silkworm coats its fibre on excreting or, as I prefer to name it, seripositing it as it issues from its seripositors.

Sericin has the formula, according to Cramer, of



He supposes it to be formed by oxidation of fibroin with simultaneous addition of water, according to the equation—



The difference of this composition to that of fibroin appears to be that it contains H_2 and O_2 more in the molecules, the carbon and nitrogen remaining the same.

The formula of fibroin, according to Staedeler, and also Mulder, is



There is a difference in the various formulæ given by Chemists; but I am inclined to think there must be a

much greater difference between the composition of sericin and that of fibroin than is here stated, and I think it would be a good thing if the analyses of both these substances were conducted anew by an able chemist accustomed to such organic investigations, and also in conjunction with it the composition of Tussur silk and its gum.

Sericin, gum, or grès is easily soluble in the degumming or boiling-off soap bath, leaving the silken fibre or fibroin intact and homogeneous, without fibrillæ being separated, when the degumming has been done with due care.

This is the normal state of silk after the degumming or boiling-off by the dyer. The development of fibrillæ is the exception, and not the rule, and points unmistakably to want of successful boiling-off or degumming, or to some previous abnormal manipulation which promotes a tendency to the exfoliation or splitting-up of the brin or single fibre of silk.

In 1889, as is stated on page 13 of the following translation, Monsieur L. Blanc observed thin, straggling filaments as the fibroin issued from the seripositor of the silkworm.

If these were of less diameter than that of the fibre or brin of the fibroin, it would go far to prove that these minute divisions were part of the construction of the ultimate fibre, plainly visible in the Saturniidæ, but invisible, until separated, in the Bombycidæ. In the Bombyx Mori silks the brin, as emitted from the seripositing exits, is not always uniformly round, but is somewhat of an ellipse.

I do not think it has yet been explained how fibrillæ can become part of a fibre which is issued in a semi-fluid state.

It would be extremely interesting to know the internal cause in both these families, Bombycidæ and Saturniidæ, of the order Lepidoptera. If owing to internal organisms coming out, so to speak, the fibrillæ

before or as they form the brin, the organs must be microscopically minute, especially in the Bombycidæ. If any investigations have been undertaken by Continental savants, I have not had the privilege of knowing of them. Such a study would be well considered at the Government Sericultural Schools at Montpellier and Padua.

The tendency of the fibres to exfoliate is greatly increased in some after-dyeing operations; for example, where silk has to undergo repeated immersions in hot soap-baths, notably after successive baths in persulphate of iron in the dyeing and weighting of blacks, and in the logwood and soap baths following, the last of which sometimes has to be sustained at boiling point repeatedly before the correct hue is obtained. In such cases, when overdone, fibrillæ become the rule, and not the exception. This is also the case in the weighting of coloured silks, now so prevalent in these modern developments for the sake of cheap production. It is hardly possible, even with the utmost care and skill, to ensure absolute avoidance of speckiness when the silk has to be extremely heavily weighted, as is so often the case in Continental dye-houses, as when 12 ounces of degummed silk is increased in weight to 32 ounces and even to 34 ounces. The processes of degumming, phosphating, alkaline baths with repeated immersions in SnCl_4 in the dyeing and weighting of colours are almost enough to threaten the stability of the fibre itself. In such instances the minute ravelled balls, specks, or fiocchetti are often to be seen in considerable numbers.

It is in the successful conducting of these multifarious and involved processes that the scientific skill of the dyer is made prominent, for without an exact knowledge of chemistry, and the chemical relations of one process to another, the silk would return from the dye-bath a more or less worthless rabble and an unsaleable mass, with diminished lustre and strength, full of the minute white specks or fiocchetti, and exceedingly difficult to be wound and woven.

SPECKINESS.

My attention, microscopically, was first called to this defect by a London silk manufacturer, who sent me a skein of silk which had been dyed red by his dyer, on which were very numerous small white specks—"fiocchetti," as in the Italian, or, as more expressively denominated in America, "lousiness."

At the first glance I thought them to be particles of some extraneous matter or sediment derived from insoluble sediment in the dye-bath, and that they would be removable by a washing or solvent agency. These treatments, however, caused the speckiness to increase, and upon a microscopic examination I found them to be firmly attached to the silk fibre, and apparently a part of it. The appearance of most of these specks is shown on Plate 1, Fig. A; furthermore, many of the specks were of the appearance as shown in Plate 2, Fig. B, the bulbous extremities being the result of some of the fibres being half dissolved by strong alkali having been used in the ineffectual effort to reduce or destroy the specks, and having fused the ends of the fibres, without altering or removing the fibrillæ.

Most of the specks seemed to contain a nidus, which caused me to suspect the presence of some parasitic eggs or larvæ; but after much careful and long-continued microscopic examination, I could not discover any foundation for this idea.

Besides the suspicion of the presence of any microscopic insect making its nidus in the silk, it also occurred to me that spiders and their fine fibres of silk might be the cause. The appearance of spider-silk is shown in Plate 3, figure A; but the microscope showed spider-silk to be too coarse in comparison with the fibrillæ.

Then there is the well-known fact that several species of the Ichneumon fly deposit their eggs in the body of the silkworm, which remain there during the pupæ

stage, when they make a cocoon of very fine silk, the size of a grain of wheat, for their chrysalis stage, which, when they emerge, has killed the silkworm. Even the *Ichneumon* fibre proves a little coarser than the fibrillæ. (See Plate 4, figure A.)

This speckiness, *fiocchetti*, or lousiness, as the Americans say, is never seen in the raw or thrown state. It is never seen before the degumming or boiling-off process, although the defect may have been commenced in cocoon-reeling if too hot or too prolonged baths have been used in which to soak and reel the cocoons.

The specks seem to be simply a tangled rabble of filaments, split off or exfoliated from the original fibre or brin, an explanation which will probably remain as the correct one now that both Italian and French savants, as well as myself, have succeeded in dividing the brin at will by chemical means, as described on page 7.

I made many laboratory experiments to this end, which show that by degumming the silk carefully in one boiling soap-bath no fibrillæ are formed, but with repeated degummings, as on Plates 5 and 6, figures A and B, the brin or fibre gets split up into numerous fibrillæ.

As far as my examination goes I have never found the defect confined to any race or quality of silk of the *Bombyx Mori*. It occurs equally in the various races or breeds of Italian, French, China, Japan, Kashmir, Bengal, or any other kind of Asiatic silk, and it occasionally occurs in silks dyed, whatever may be the colour or shade; it is to be noticed sometimes in silks dyed black when unweighted.

THE FIBRILLÆ OF THE WILD SILKS.

Although it would seem an impossibility for a fibre as fine as the 1/1900th of an inch, as is the brin of the *Bombyx Mori*, to undergo sub-division, when one considers its apparently structureless nature both to the unassisted eye and under the highest power of the

microscope, it may probably add to the interest of the subject if I give a few plates of the microscopical appearance of several of the most prominent species of the Saturniidae and their silken fibres.

The silk-producing Lepidoptera are divided by Naturalists into several families—Bombycidae, to which *Bombyx Mori* belongs (see Plates 7 to 10), and Saturniidae, to which the flattened-fibre silk producers belong, at least those which I have selected for illustration and description, and also Eupterotidae, to which belong the new Silks from Lagos, the Gold Coast, Northern Nigeria, and Uganda, of which I give drawings on Plates 29 to 35, and which I have been examining for the Imperial Institute.

The first Saturniidae silk producer is that called Tussur, Tussah, or Tussore, from the Hindu word “Tusuru,” a shuttle, of which there are now two well-known industrial species, the Indian, *Antheraea Mylitta*, which feeds on the leaves of sub-tropical plants, principally *Shorea robusta* and *Terminalia tomentosa*; and the Chinese species, *Antheraea Pernyi*, the larva of which feeds on the leaves of various species of the oak, *Quercus Mongolica*, and notably on the evergreen oak, *Quercus Ilex*.

Twenty-five years ago the silk of these two species found no utilisation in Europe, but gradually there has sprung up a very large and growing utilisation, especially of the Chinese species, as much as upwards of 300 bales, or 40,500 lbs. per week, passing through the Lyons conditioning house. For the week ending 30th April, 1908, 521 bales = 70,335 lbs. were conditioned, besides a large quantity being weekly conditioned in Milan; also very large quantities of native woven Tussur fabrics, called Shantung and Honans, are regularly arriving from native looms in China and India, for motor-dress purposes and other garments in European and American centres, where during late years they have become so deservedly popular.

Tussur silk is very untractable to ordinary dyeing operations, particularly to the older processes and dyes, and it is with considerable pride that I look back on my successful efforts and studies of past years to conquer the difficulties of dyeing Tussur silk, before these difficulties were overcome in Lyons and other great Continental dyeing centres.

The fibre of the Indian Tussur silk is $1/620$ th of an inch in diameter, that of the Chinese Tussur being $1/760$ th of an inch, that of the Italian silk of the *Bombyx Mori* $1/1900$ th of an inch, of *Bombyx fortunatus* of Bengal $1/2000$ th of an inch. It is interesting to notice the ribbed appearance of the fibres of these silks, as indeed of those of the family of Saturniidæ generally. The darker striations appear to be of solid silk, whilst the lighter parts consist of somewhat less soluble silky matter, which it is not easy to detach from the more fibrous part.

Plates 11 to 14 give an accurate representation of Indian Tussur silk, and Plate 15, Figs. A to C, of Chinese Tussur silk. Each plate is fully described on the pages opposite to the respective species and illustrations.

The silk of Kashmir, obtained from the *Bombyx Mori*, from European eggs, is a comparatively recent importation and production. The fibre is round and translucent, without any appearance of fibrillæ.

In 1897 I suggested to the Government of India that, as the mulberry was indigenous and abundant in the State of Kashmir, and the population in great distress and disease, it would be well for sericulture to be commenced there on a scientific and practical basis. My suggestion was approved of, and silkworm-eggs were purchased by me in Europe, also cocoon-reeling machinery, and these were sent out. I selected a Director for the post, a Mr. Walton, who had been Assistant-Director of Sericulture, at Surdah, for nearly twenty years, and afterwards Director there, a very competent

man, who was appointed by the Maharaja, the Durbar, and Sir Adelbert Talbot, who was at that time the Resident of Kashmir, and who took great interest in the opening and expansion of the industry, and to whom much of its success is due. Since that time the industry has grown into colossal proportions. There are now ten large factories at Srinagar, the capital of Kashmir. Each employs 560 men and boys in reeling cocoons. There are over 1,000 bassines, or reeling basins—a most gratifying progress which has every promise of annual increase. The number of village householders who now take out silkworm eggs is 15,784, and as their wives and children are occupied in feeding the silkworms and attending to the details of silkworm rearing, their number, supposing four persons in each family, assisting in this industry may be roughly estimated at between 60,000 and 70,000 people in this new industry. It is, besides, a most profitable industry; the profit for the working of the Sericicultural Department for the year 1906 was £30,500, and will prove to be considerably more for 1907.

The crop of cocoons for 1907 is a record one, being no less than 28,000 maunds, which is equal to 1,100 tons, or to 2,464,000 lbs.

The following table shows the gradual increase in the production of raw-silk in Kashmir since the commencement :—

Out-turn of raw-silk for 1899.....	22,500 lbs.
„ „ „ 1900.....	57,921 „
„ „ „ 1901.....	90,648 „
„ „ „ 1902.....	135,221 „
„ „ „ 1903.....	146,087 „
„ „ „ 1904.....	132,451 „
„ „ „ 1905.....	152,425 „
„ „ „ 1906.....	190,736 „

I have also successfully introduced Silk Weaving there, at the wish of the Maharaja and under his ægis, and

there are over 212 looms at work, native Kashmiris having been taught to weave in them the finer silks, which are competing successfully with those of Japan. The raw-silk produced and exported is from the same race of eggs as that from which the celebrated raw-silk of the Cevennes is obtained, and it commands correspondingly high prices, and is therefore of much greater value than the raw-silk of Bengal. It is, of course, one of the best cultivated races of the *Bombyx Mori*, and has no relationship or similarity to either the silk of Bengal or the wild silks of India or China.

I have lately received four specimens of Cluster or Colony Cocoons from West Africa; one from Lagos, sent by Mr. J. S. Fletcher, of Ofado, Abeokuta (there were two different clusters, one having a hard shell and the other a soft shell), another from Dr. Graham, of Ashanti, Gold Coast; and two from Professor Wyndham Dunstan, Director of the Imperial Institute, London, one of which is from Uganda and the other from Northern Nigeria. See Plates 29 to 35.

The Uganda silkworm feeds principally on the leaves of a species of *Ficus*, but the cocoons are found in almost all the forest trees. The caterpillars construct a large nest, inside which they form their cocoons in considerable numbers. These nests are composed entirely of silk. The outer layers are of somewhat loose texture, while the inner part is firm and paper-like, but, on degumming, each portion yields the same silky material. It seems probable that the whole of this product may be capable of utilisation as "waste" silk.

On examining the cocoons it has been found possible to reel a small quantity of silk from selected specimens, but usually they are too loose to allow the reeling to be satisfactorily carried out. Technical trials have shown that the whole of the silk can be spun into lustrous yarns, which can be dyed without difficulty.

With regard to those from Nigeria, the silk is used by the natives in conjunction with cotton for making the so-called "soyan" cloths. There appear to be several varieties of these silkworms, and they probably occur in many parts of Africa.

All these four specimens of Cluster Cocoons are extremely interesting, and they all appear to be of the Family Eupterotidæ. Those from Mr. Fletcher, of Lagos, are *Anaphe Infracta* (Walsingham), that from Uganda being *Anaphe Molonei* or *Panda*; but the other two, that is those from Northern Nigeria and the Gold Coast, are of the same genus, namely, *Anaphe*, but possibly other species.

I have not been able to see the Moths of any of them except that of *Anaphe Infracta*, a drawing of which is shown in Plate 31, Fig. D.

The fibres appear to be more or less round, and but little resembling those of the Saturniidæ. Fibrillæ structure may be observed under the microscope here and there.

The Cocoons of *Anaphe Infracta* are very small and are shown in Plate 29, Fig. A; and of *Anaphe Molonei* or *Panda* in Plate 31, Fig. E; and on Plates 33 and 35 the Cocoons from Northern Nigeria and the Gold Coast.

In conclusion, the result of all these examinations and discoveries is that the freedom from divisibility of the ultimate fibre must be obtained by the experienced judgment of the dyer, for, once divided, there is no cure for it, and it is absolutely a case of prevention.

In order to prevent the silk fibre from splitting up and dividing into fibrillæ, it is necessary to point out that great care should be taken—

(1) During the battage and reeling of the cocoons, that they should not be too long exposed to water greatly heated;

(2) In degumming or boiling-off by the dyer the greatest care, judgment, and experience must be used, so that the silk be not too much disturbed or remain too long in the highly-heated soap bath ;

(3) In the dyeing, especially in prolonged processes, the silk should be gently handled, and not dyed at too great a heat. It is impracticable to give specific directions as to temperature.

PLATE 1.

FIGURE A.

Silk dyed red, with white specks or "fiochetti." Magnified 40 diameters, and showing the speckiness to consist of fibrillæ.

PLATE I.



FIGURE A.

PLATE 2.

FIGURE B.

Silk dyed red, with white specks or "fiocchetti." Magnified 40 diameters, and showing the speckiness to consist of fibrillæ with swollen and semi-fused ends from misuse of caustic alkali.

PLATE 2.



FIGURE B.

PLATE 3.

FIGURE A.

Spider Silk. Magnified 40 diameters.

PLATE 3.



FIGURE A.

PLATE 4.

FIGURE A.

Silk Fibre of Ichneumon Cocoon. Magnified 40 diameters.

PLATE 4.

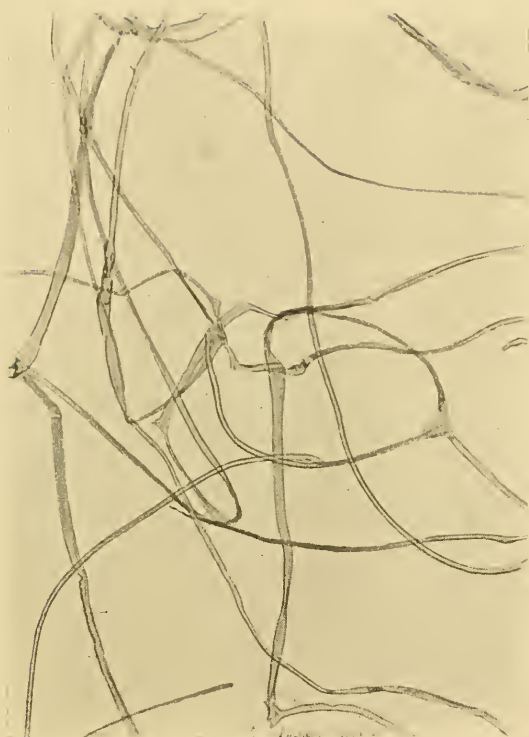


FIGURE A.

PLATE 5

FIGURE A.

Overworked by being experimentally boiled-off or degummed six times. Showing separation of the brin into numerous fibrillæ. Magnified 60 diameters.

PLATE 5.



FIGURE A.

PLATE 6.

FIGURE B.

Much Overworked in Degumming and Dyeing. Magnified 45 diameters.

PLATE 6



FIGURE B.

PLATE 7.

FIGURE A.

The Bombyx Mori Moth of France and Italy (Male).

FIGURE B.

Bombyx Mori Moth (Female).

PLATE 7.



FIGURE A.

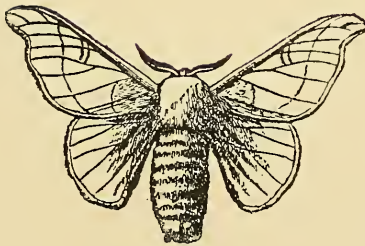


FIGURE B.

PLATE 8.

FIGURE C.

Silkworm or larva of the Bombyx Mori, feeding on the Mulberry-leaf.

Monsieur Laurent de l'Arbousset's book on Sericulture is a most useful and practical guide to Sericulture. It was translated from the French in 1905 by my daughter Elizabeth Wardle, and published by Mr. W. H. Eaton, of the Moorlands Press, Leek, price 2s. 6d. net in paper backs, and 3s. 6d. in cloth backs. Furnishes all particulars relating to mulberry culture, silkworm rearing, and the reeling of cocoons.

FIGURE D.

Cocoon of Bombyx Mori, French. Actual size.

PLATE 8.

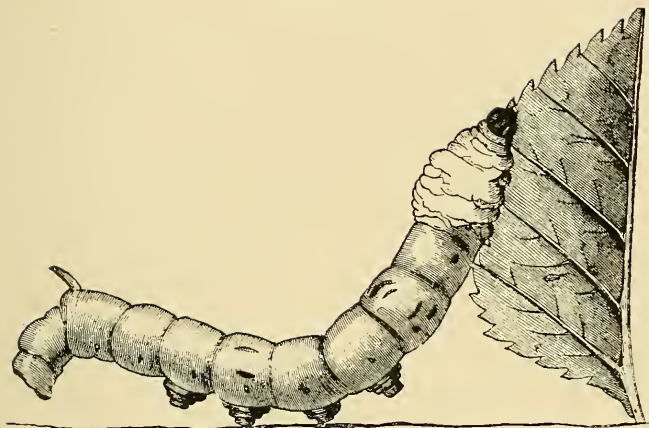


FIGURE C.

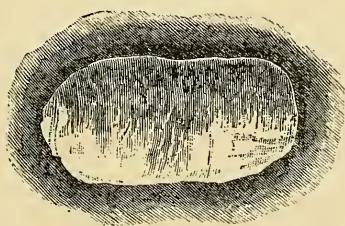


FIGURE D.

PLATE 9.

FIGURE E.

Silk of *Bombyx Mori*, showing the longitudinal fibres as issued in pairs from the seripositor of the silkworm. The single fibre is termed brin, and the double fibre have. The rounded spots are transverse sections of the have. Magnified 500 diameters.

FIGURE F.

Baves of the Silk of *Bombyx Mori* or Silk of Commerce.

PLATE 9.

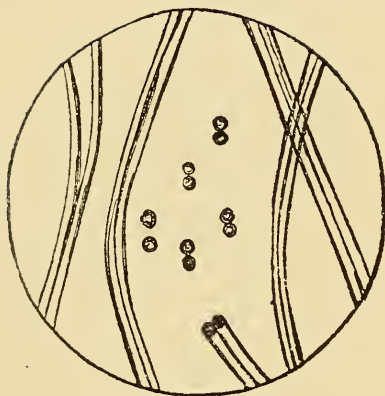


FIGURE E.

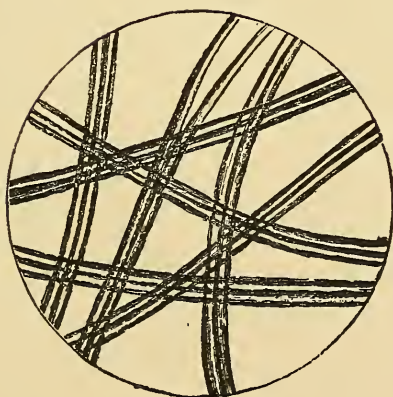


FIGURE F.

PLATE 10.

FIGURE G.

Bombyx Mori, with Fibrillæ.

Silken fibres from the loom, showing speckiness, fiocchetti or lousiness solely due to fibrillæ.

PLATE 10.



FIGURE G.

PLATE II.

FIGURE A.

Antheræa Mylitta or Indian Tussur or Tussore Silk Moth (Male.)

FIGURE B.

Antheræa Mylitta Moth (Female).

PLATE II.

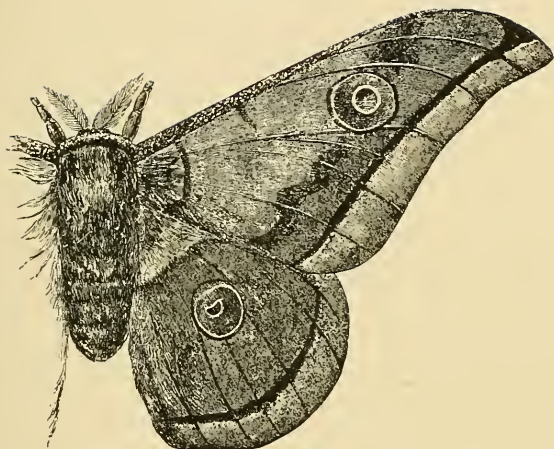


FIGURE A.

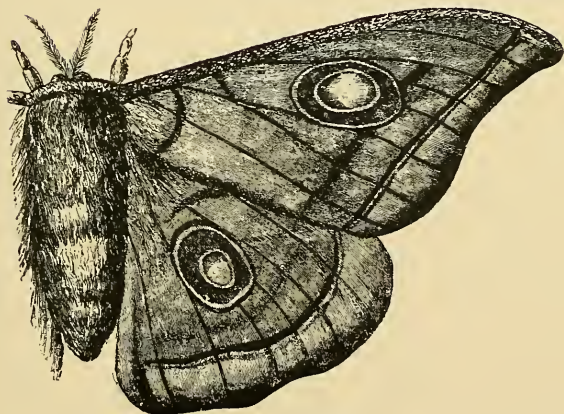


FIGURE B.

PLATE 12.

FIGURE C.

Silk of *Antheræa Mylitta* or Indian Tussur Silk (microscopic appearance), showing divided fibrillæ, or the divisions produced in 1880 by myself, by means of permanganate of potassium, showing also the flat sections of the fibres.

FIGURE D.

A Cocoon Fibre of Tussur, showing a few Fibrillæ.



FIGURE C.



FIGURE D.

PLATE 13.

FIGURE E.

Larva of *Antheræa Mylitta*, or Tussur Silkworm; natural size. Considerably larger ones are generally found.

FIGURE F.

Tussur Cocoons with their pedicles, showing their natural attachment to the boughs of the trees on the leaves of which they feed. The horny pedicles are composed of great numbers of the silk threads they seriposit, so as to form a thick resistant rosey stalk by which they attach themselves to the branches of trees to prevent their destruction by falling, which would occur did their attachment be to the leaves, as is the case with many of the species. Natural size.

PLATE 13.

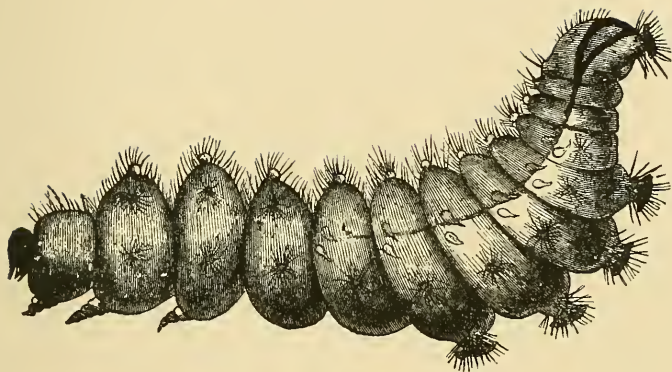


FIGURE E.

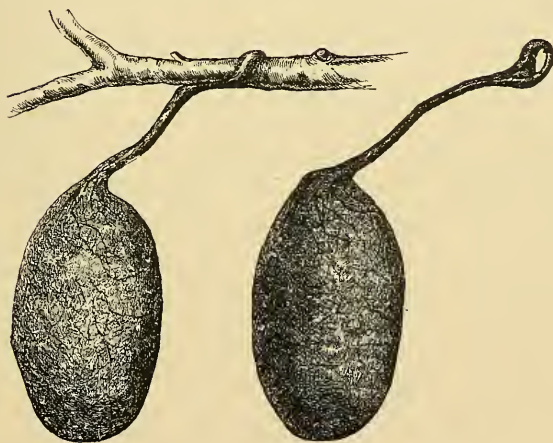


FIGURE F.

PLATE 14.

FIGURE G.

Tussur Cocoon, Indian, cut open to show the chrysalis inside. Natural size. The shell is all silk, which, when properly softened, is capable of being reeled off in a continuous thread. In Italy, when I was sent down by the Government of India to try to discover a better method of reeling Tussur Cocoons than that practised in India, I obtained from one cocoon a continuous silk thread three-quarters of a mile long.

PLATE 14.

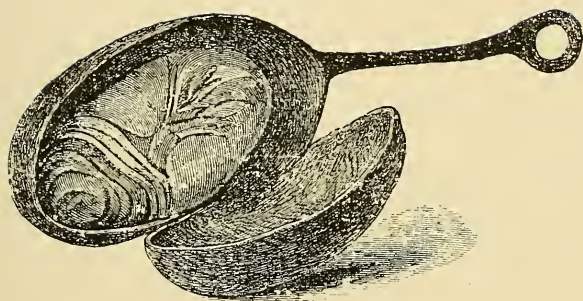


FIGURE G.

PLATE 15.

FIGURE A.

Moth of *Antheraea Pernyi*, or Chinese Tussur Silk Moth (Male). This is the Oak-feeding silkworm of Manchuria. It is described as having been long known to the Manchur Tartars, as very large quantities of silk were used amongst the Chinese. The worms feed on various species of Oak, *Quercus Mongolica*, and also on the evergreen oak, *Quercus Ilex*.

FIGURE B.

Cocoon of *Antheraea Pernyi*, or Chinese Tussur Cocoon. Natural size. The Chinese Tussur Cocoons differ from the Indian ones in both form and texture.

FIGURE C.

Microscopic appearance of the Double Fibre or Bave of *Antheraea Pernyi*. The species from which the Silk Cloths called Shantung and Honans are made.

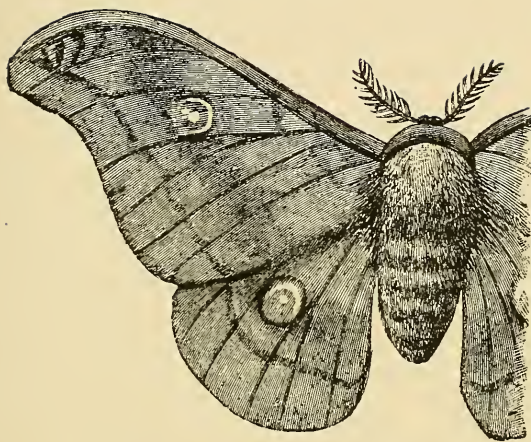


FIGURE A.

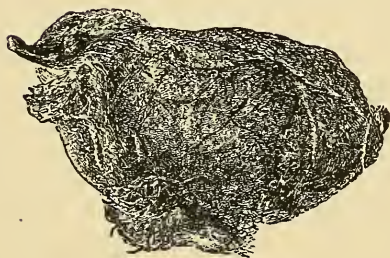


FIGURE B.

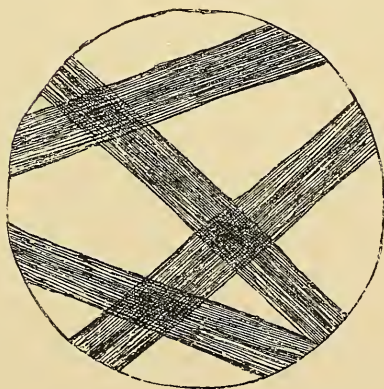


FIGURE C

PLATE 16.

FIGURE A.

Moth of *Antheræa Assama*, or Muga Moth. Assam, India. Male. Natural size.

FIGURE B.

Larva of *Antheræa Assama*, or Muga Silkworm. Natural size.

PLATE 16.

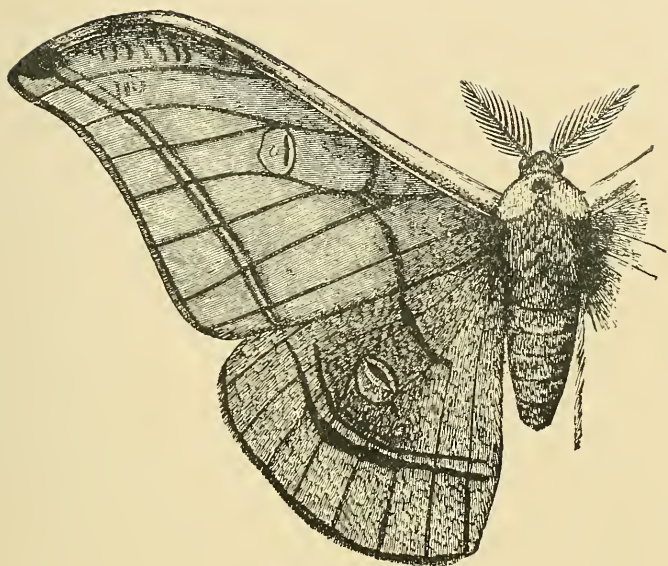


FIGURE A.

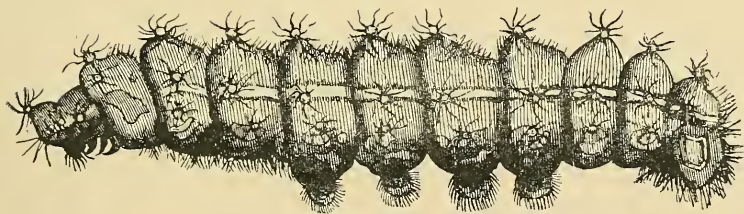


FIGURE B.

PLATE 17.

FIGURE C.

Cocoon of *Antheræa Assama* or Muga Cocoon. Natural size.

FIGURE D.

Silk of *Antheræa Assama*, or Muga Silk. This silk is the next in structural importance to Tussur, and has great promise of utilization if the natives could be induced to grow it in quantity for export to Europe. The plate shows the microscopic appearances of the pairs of silk fibres as seriposited by the worm.

PLATE 17.

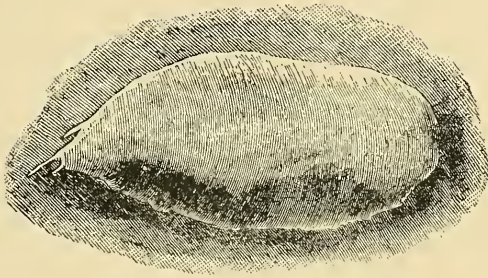


FIGURE C.

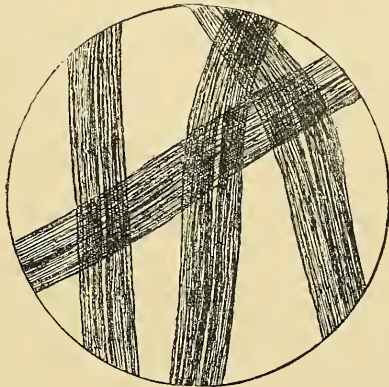


FIGURE D.

PLATE 18.

FIGURE A.

Moth of *Antheræa Yama-mai*, Japan (Female). This species is a native of Japan, although it is found also in China, and has been introduced into India, though very sparingly. Natural size.

FIGURE B.

Larva or Silkworm of *Antheræa Yama-mai*. Natural size. This feeds on the Oak leaf.

PLATE 18.

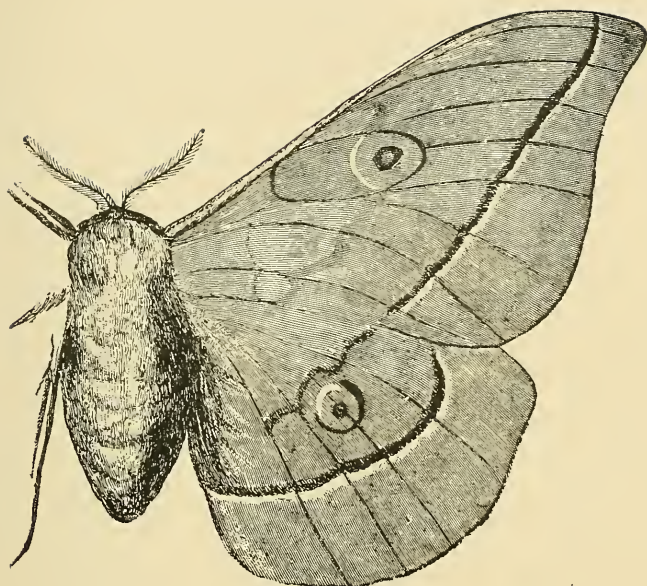


FIGURE A.

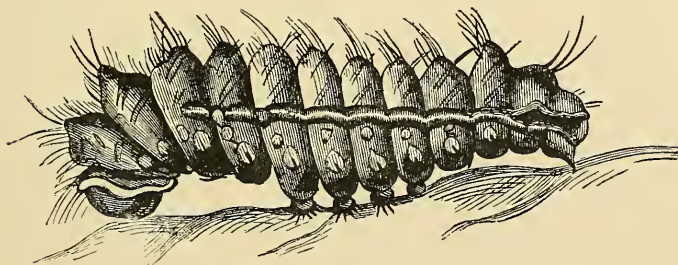


FIGURE B.

PLATE 19.

FIGURE C.

Cocoon of *Antheræa Yama-mai*. Actual size

FIGURE D.

Silk from outside of Cocoon of *Antheræa Yama-mai*. Magnified 40 diameters. This silk was formerly exclusively used by Japanese Royalty. It belongs to the family Saturniidæ, and its fibre is ribbed like that of Tussur silk. It is a most useful species of silk, although of a coarser fibre than that of *Bombyx Mori*, and has a very glossy appearance, being flat and striated. The diameter of the fibre is 1/1000th of an inch.

PLATE 19.

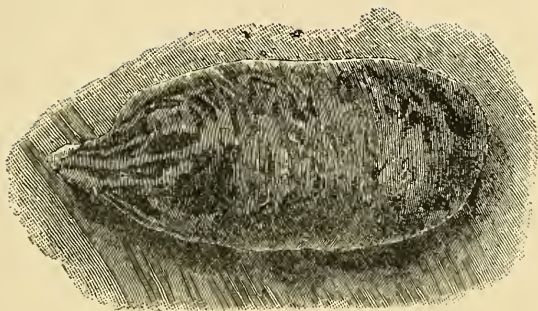


FIGURE C.



FIGURE D.

PLATE 20.

FIGURE A.

Moth of *Actias Selene*. India (Male). Natural size. This species has a most beautiful moth, as is shown by the illustration.

FIGURE B.

Larva or Silkworm of *Actias Selene*. Natural size. This worm feeds on the *Andromeda ovalifolia* (*Coriaria nipalensis*), wild cherry and walnut at Mussooree, and on the *Odina wodier* in Madras.

PLATE 20.

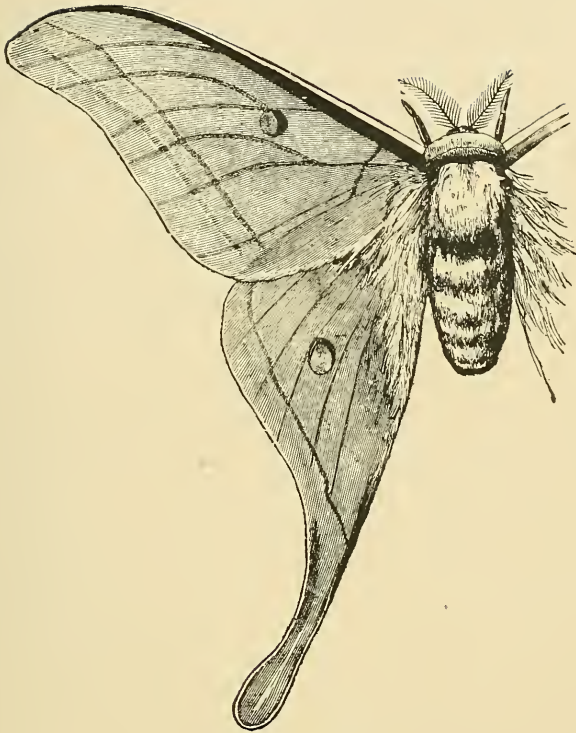


FIGURE A.

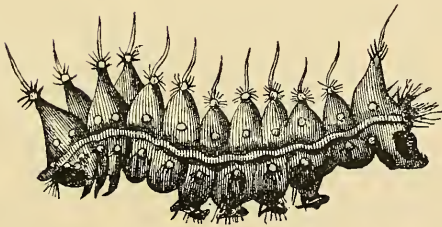


FIGURE B.

PLATE 21.

FIGURE C.

Cocoon of *Actias Selene*, inside a leafy envelope. The cocoon is rather large, being 3 inches long and $1\frac{3}{4}$ inches in diameter. The silk from the cocoons is not windable, but it is of a coarsish kind and could be spun if it could be obtained in sufficient quantity.

FIGURE D.

Microscopical appearance of the Silk of *Actias Selene*, bave or double fibre.

PLATE 21.

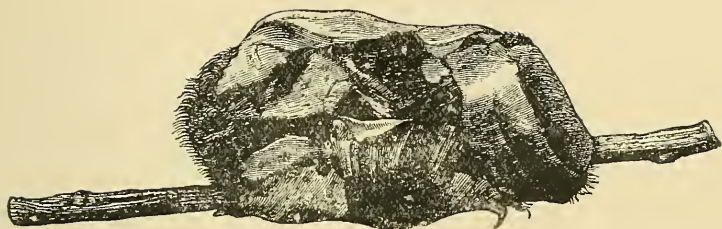


FIGURE C.

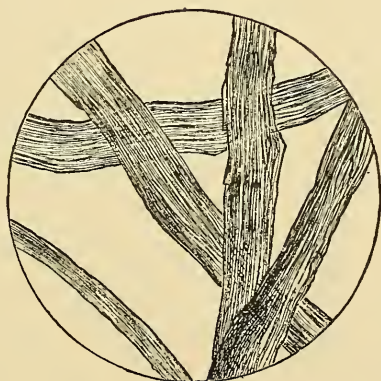


FIGURE D.

PLATE 22.

FIGURE A.

Moth of *Philosamia Ricini* (formerly *Attacus Ricini*) (Male). Natural size. This is the Eri or Eria Moth, found chiefly in Assam. The silkworm feeds on *Ricinus communis*, or castor-oil plant, and the value of Eria Cocoons commercially is from 1s. to 1s. 6d. per lb.

FIGURE B.

Silk of *Philosamia Ricini*, or Eria Silk. This silk is about one-half finer than Tussur silk, although not more than two-thirds as fine as the silk of *Bombyx Mori*. It is difficult to wind or reel, and the only way to develop an extensive industry would be to have the cocoons carded and spun. Woven cloths of great strength and durability are made in Assam from yarns carded and spun by hand from Eria silk, and the yarns are of great regularity, proving this silk capable of uses for spinning and weaving purposes to an unlimited extent when grown and exported in quantity.

PLATE 22.

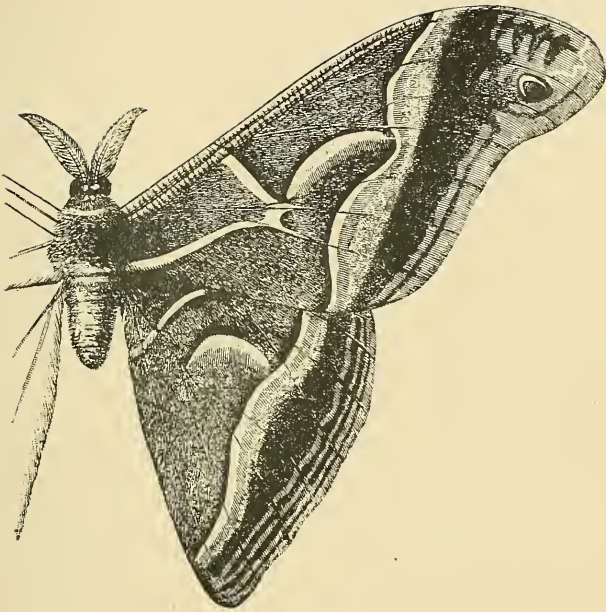


FIGURE A.

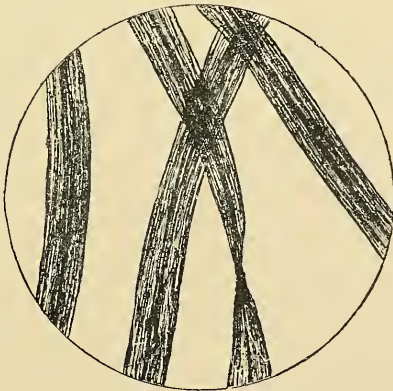


FIGURE B.

PLATE 23.

FIGURE A.

Moth of *Attacus Atlas*, India. (Male). These moths are the largest of the family Saturniidae, some of the specimens found being 10 inches across. Natural size.

PLATE 23.



FIGURE A.

PLATE 24

FIGURE B.

Microscopic appearance of Bave, or Double Fibre, of Silk of Attacus Atlas. The fibres are flat and longitudinally striated, and the silk is difficult to reel, but is used in Nepaul, hand-carded, spun, and woven into very coarse cloth.

PLATE 24.

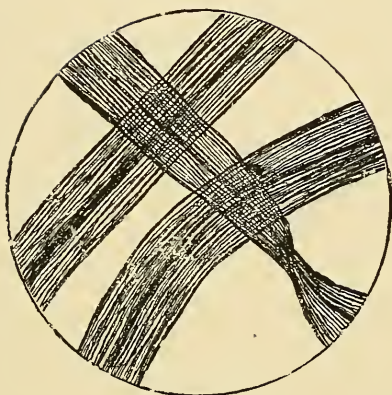


FIGURE B.

PLATE 25.

FIGURE C.

Silk from outside of Cocoon of *Attacus Atlas*, showing Fibrillæ. Magnified 40 diameters.

PLATE 25.

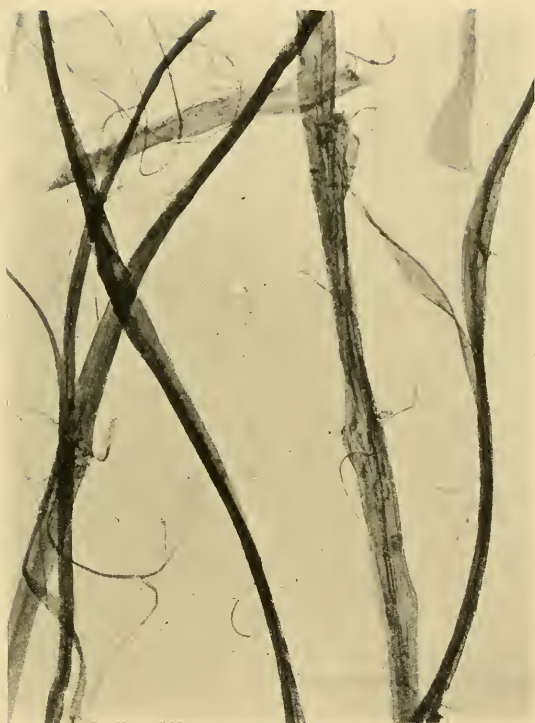


FIGURE C.

PLATE 26.

Loose outside of Cocoon of *Theophilus Huttoni*. Family Bombycidæ, India.
Magnified 40 diameters.

PLATE 26



PLATE 27.

Double fibre of *Loepa Katinka*. Family Saturniidae, India.
Magnified 40 diameters.

PLATE 27.

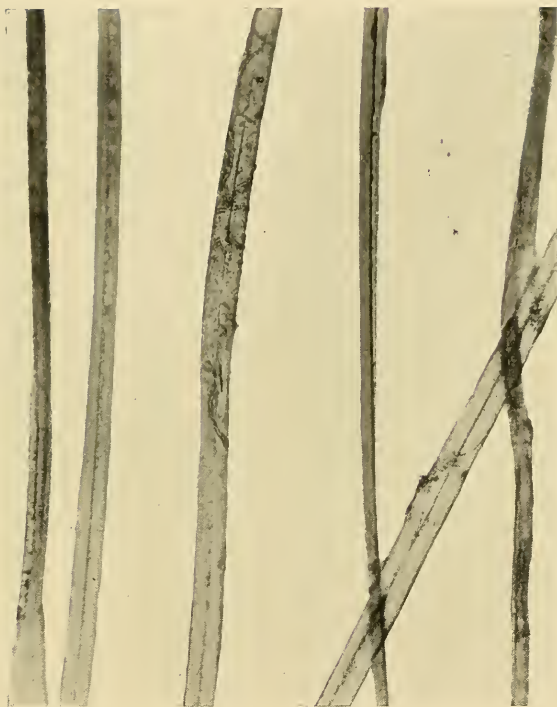


PLATE 28.

Silk of *Attacus Aurota*, showing Fibrillæ. Family Saturniidæ, a South American species. Magnified 40 diameters.

PLATE 28.



PLATE 29.

FIGURE A.

Cocoon out of one of the two Cluster Colonies of Cocoons, from Mr. Fletcher, of Abeokuta, Lagos, Africa. Family, Eupterotidæ. Genus, Anaphe. Species, *Infracta* (Walsingham). Natural size $1\frac{2}{10}$ inches long $\times$ $\frac{1}{2}$ inch wide; oval. This cluster from which the cocoon was taken, had a hard silk shell; the other had a soft shell. Numerous colony of Cocoons enclosed in hard shell and in a bag or thick silken film inside the shell.

FIGURE B.

Fibre of the Cluster Colony of Cocoons, with hard shell, from Mr. Fletcher, Lagos. Magnified 40 diameters. Thin fibres, very irregular, composing the hard shell softened and divided by boiling in water and soda, and then pulled by hand; ribbony.

PLATE 29.

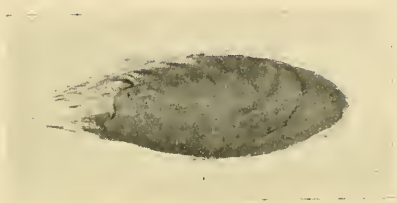


FIGURE A.



FIGURE B.

PLATE 30.

FIGURE C

Fibre from soft shell of the other Cluster Colony of Cocoons, from Mr. Fletcher, of Lagos. Magnified 40 diameters.
The Cocoon of this closely resembles that of the foregoing—*Anaphe Infracta*.

PLATE 30.



FIGURE C.

PLATE 31.

FIGURE D.

Moths of *Anaphe Infracta* (Walsingham). Natural size. From the Cluster Colony of Cocoons from Lagos, with hard shell. From this Colony a dozen Moths emerged.

FIGURE E.

Cocoon out of Cluster Colony of Cocoons from Uganda, received from Professor Wyndham Dunstan, Director of the Imperial Institute, London. Family, Eupterotidæ. Genus, *Anaphe*. Species, *Molonei* or *Panda*. Natural size.

PLATE 31.



FIGURE D.

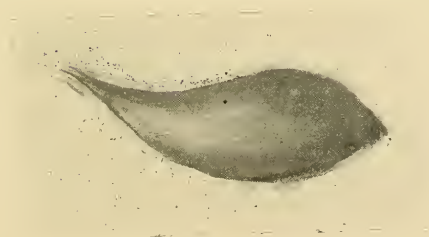


FIGURE E.

PLATE 32.

FIGURE F.

Fibre of Uganda Cocoon. *Anaphe Moloneï*, or *Panda*. Magnified 40 diameters.

PLATE 32.



FIGURE F.

PLATE 33.

FIGURE A.

Cocoon from Cluster Colony of Cocoons, from Northern Nigeria, sent by Professor Wyndham Dunstan, Imperial Institute, London. Family Eupterotidæ. Genus, *Anaphe*. Species not known. Natural size. This Cocoon is preceded by a long, protecting soft tube of the same kind of silk as the Cocoon.

PLATE 33.

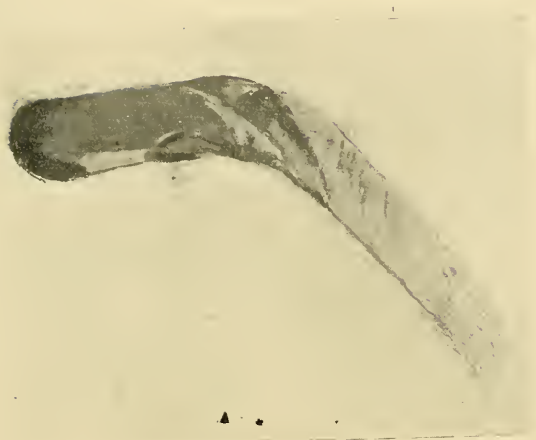


FIGURE A.

PLATE 34.

FIGURE B.

Fibre of Cocoon from Northern Nigeria. Magnified 40 diameters.

PLATE 34.



FIGURE B.

PLATE 35.

FIGURE A.

Cocoon from Cluster Colony of Cocoons, sent to me by Dr. W. Graham, of Obuasi, S. Ashanti, Gold Coast, West Africa, on the 15th of October, 1907. Family Eupterotidæ. Genus, *Anaphe*. Species not known. Natural size. Sizes of the Colonies, 6 ins. long by 3 ins. broad, enclosed in twigs of trees in which the Cocoon bags are constructed. Leaves are attached to some of the bags. Cocoons, almond-shaped, $1\frac{1}{2}$ in. long, by $6\frac{1}{10}$ of an inch broad.

FIGURE B.

Fibre of Cocoon from Gold Coast. Magnified 40 diameters. The Cocoons are enclosed in small silken bags, and the fibres of the silk are round; indications of fibrillæ, but no appearance of them under power of Koristka's No. 7 objective, enlarging 275 diameters.

PLATE 35.



FIGURE A.

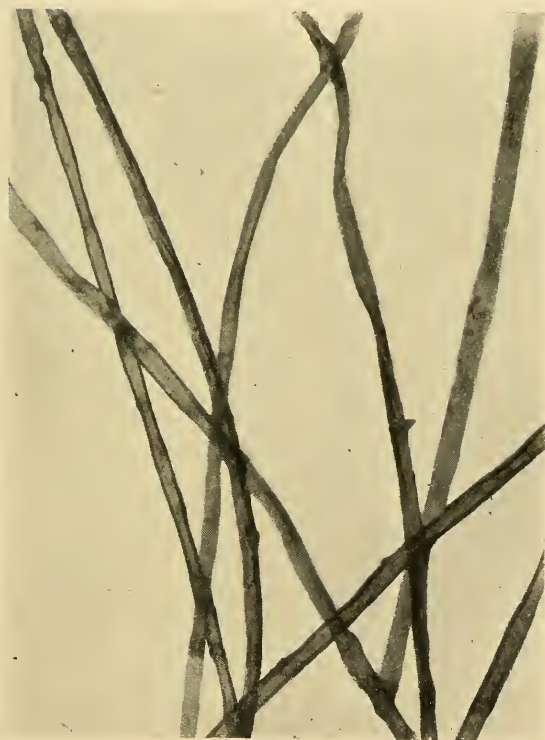


FIGURE B.

APPENDIX.

FACE-MARKS ON JAPANESE HABUTAYE AND HONAN SILKS, AND ALSO UPON CHINESE PONGEES AND SHANTUNGS.

I regret it was not possible before this book was printed to include the results of an extended research I have made with respect to a very frequently recurring defect in Silks woven in the gum in China and Japan, and degummed or boiled-off and calendered there after weaving, when large and small apparent stains, called “face-marks,” occur on surface portions of both sides of the fabric, which are not removable, and which, after being dyed and finished in England, appear in a much more pronounced manner.

It is generally difficult to detect the presence of the “face-marks” in the grey, owing to the stain-like appearance being so near the colour of the cloth. The defects only become definitely apparent as soon as the Silk has been subjected to dyeing and finishing.

Microscopical examination proves that these defective markings or apparent stains on the Silk are due to the improper treatment they have undergone in the earlier stages in the East which causes abrasion or divisibility of the fibres into fibrillæ, as explained in the foregoing pages, making roughened and velvety surfaces, and are, as already stated, owing to unskilful and unscientific degumming or boiling-off, and perhaps, also, to too severe treatment in the calendering operations in preparing them for the export market in the grey. These defects are incurable but preventible, and would not occur if the Silks were sent over undischarged and uncalendered to England, where they would be subjected to more skilful and scientific procedure, or if properly degummed and calendered in the East.

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On the Divisibility of the Ultimate Fibre or Brin of Silk.



*Report of an Investigation carried out
under the auspices and in the Laboratory
of the Societa Anonima Co-operativa per
la Stagionatura e l'Assaggio delle Sete ed
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1903.

THE AIM AND SCOPE OF THIS BROCHURE.

[TRANSLATION.]

FOR some years past silk manufacturers have followed with great interest certain studies which sought to discover the causes of a defect that is sometimes seen on the Silk fibre after the dyeing operations, for the reason of which the most diverse conjectures have been put forth.

This serious defect consists of little roughnesses or inequalities, caused by microscopic specks, slubs, or excrescences (called also "flocons," "pelotons," and "fiocchetti") of very fine fibrillæ, unevenly distributed, and of a lighter colour than the brin or material of which they are formed. In the weaving operations these slubs or fiocchetti hinder the free running of the thread, and cause it to break frequently as it passes across the comb; besides which it dulls the brightness of the material, and none of the means hitherto tried have succeeded in overcoming the depreciation of the tissue caused by them.

This defect was first seen about ten years ago on threads obtained from various sources, which had been dyed in the best dyeworks of Lyons, Crefeld, Zurich, Como, and England.

Judging from their appearance, the roughnesses were at first thought to be little grains of atmospheric dust which is sometimes scattered over the threads, but their extraordinary resistance to brushing or washing very quickly persuaded the manufacturers of a different origin.

The strangest hypotheses were afterwards put forward as to the source and the nature of these slubs or excrescences. Some believed them to be due to a defect in the reeling, throwing, or manufacture; others attributed them to a microbe, which found on the thread or brin a substance suitable to its development; and some even

ascribed it to an abnormal appetite and digestion in the silkworm, which caused it to emit, contemporaneously with the fibres or brins, incompletely digested vegetable particles.

Some of these assertions would not have been worth notice if they had not figured in public documents and in technical literature, in which are found important differences of opinion, sometimes leading to litigation between Dyers and Manufacturers.

The upholders of these absurd hypotheses tried to find confirmation in the fact that these whitish excrescences did not take the dye in the same manner as the rest of the thread, and for this reason they asserted them to be formed of cellulose, or some such substance. Not less serious was the assertion that the defect was characteristic of silks coming from certain sources, and that it might be imputed more especially to the species of worm, and to the methods of rearing, or to the manner of disinfection.

How far the prevailing ideas were from the truth is proved by the fact that not long ago a Russian manufacturer sent to our laboratory the accompanying sketch (see Plate 1), prepared under the microscope, asking us to study the insect that had eaten the silk thread; and recently the Vice-Director of the municipal laboratory in one of the principal centres of silk culture, to whom a skein previously examined by us was submitted, believed he had discovered foreign particles of a vegetable nature (cotton, vegetable, or wood) imprisoned in the silk thread, and his idea was that they might find their origin in the dyeing vats.

As we shall see afterwards, the cases above referred to were owing to phenomena which could only be shown by the aid of scientific investigation and the microscope.

The aim of this publication is to enlighten Silk Manufacturers as to the true nature of these excrescences or *fiocchetti*, in order that mistaken ideas about their origin may cease, and that the means of avoiding them may be better known.

The gravity of the damage caused by the excrescences was first pointed out by the director of this laboratory in 1895, on the occasion of the third Congress of Bacology or Sericulture, held in Cuneo. In 1896 Professor Lenticchia, of the Technical Institute of Como, studied very minutely, under the microscope, the damaged silks, and afterwards we ourselves made them an object of study.

Also Signor A. Conte and Dr. Levrat, of the Laboratory for the Study of Silk, at Lyons,¹ and

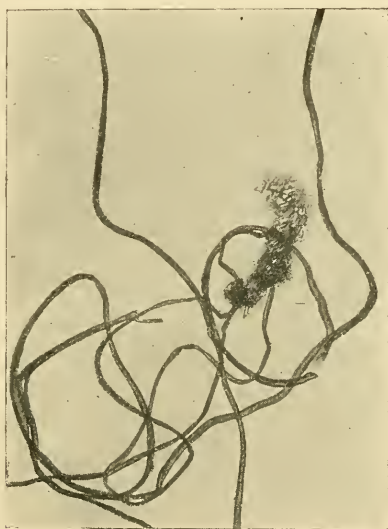


PLATE I.

Professor E. Quajat, of the R. Stazione Bacologica, Padua,² instituted similar experiments.

As a consequence of these researches, the nature of the defect, as regards its composition and the manner in which the balls, slubs, or fiocchetti are formed, has been

¹ D. Levrat e A. Conte. An Account of the Study of Silk in the Lyons Laboratory. 1901-1902.

² E. Dott Quajat. Dei bozzoli più pregevoli che preparano i lepidotteri setiferi. Padova, 1904.

perfectly cleared up, and it is proved that they are the result of the formation of very fine fibrillæ, the diameter of which is sometimes less by one-tenth, and sometimes more than that, of the degummed brin or single fibre of the silk.

These roughened or ravelled threads were called "fiocchetti"¹ by the manufacturers, and, being formed of fibroin, they took the colouring matter very well, as is shown by microscopical examination; but they are lighter in colour than the thread by reason of their extreme fineness, and from the same cause which makes the dust from coloured glass appear almost colourless, or the débris of black marble grey, in the same manner that we always see that the foam of a coloured liquid is lighter in colour than the liquid itself.²

Our present publication is a résumé of what is at present known on this question, the result of publications which have already appeared, with the addition of new experiments, which help to elucidate some particulars not devoid of interest.

The micro-photographs found in this work were prepared in our laboratory with a Koristka micrographic apparatus.

¹ The Swiss dyers call this defect "farbstaub" or "seidenlaus"—that is, dust from dyeing, or silk louse; and it is known to the French as "perlage."

² On the influence that the diameter of the thread exercises with regard to inequality of colour. See the pamphlet presented to the Chemical Society of Milan by Professor G. Gianoli (Vol. IX., Nos. 5 and 6, 1904).

CHAPTER I.

Structure and Morphological Defects of the Silk Fibre.

IN order to better demonstrate the phases through which we know the silk fibre passes, and the modifications to which it is susceptible with regard to the defect which we propose to study, it will be better, first of all, to re-state what has been already published about this question.

It is known that the silken matter (sericin and fibroin) secreted in special cells in the posterior and middle cells of the two "seritteri" of the silkworm takes the form of fibres in passing through the excretory tubes at the head of the silkworm. At the exit of the latter, the two issuing threads or brins which form the silk or bave of the cocoon unite along their line of contact.

But the silk does not form a thread absolutely uniform in all its length; its section, which is nearly an irregular ellipse, varies sensibly according to the different portions examined.

The thickness of the thread generally decreases in the interior layers of the cocoon; but this diminution does not happen in regular proportion, neither does the section decrease gradually and symmetrically; in fact, towards the last layers of the cocoon the silk has a tendency to assume a flattish or ribbon form. Therefore the comparison made by Cornalia between the silk and a very long cone, having its base at the beginning and its summit at the end, is inexact.

Not rarely the fibre or brin presents other irregularities of structure. The sericin or attachment-gum between the two fibres or brins is not generally complete

in all its length. Under the microscope of only medium power one can easily observe imperfectly agglutinated spaces and places where one fibre or brin, rendered longer than the other by reason of some rapid movement by the silkworm, or by the unequal pressure of the two "seritteri" ducts or glands, forms a loop or irregularity disjointed from its companion, which does not occur where the dual fibres keep their proper length; also the internal section or axis of the fibroin is not absolutely regular.

Blanc, in 1888, tells us that he had observed, with regard to the principal issue of the fibroin, that some thin straggling finer filaments were parallel with the main axis. This Author attributes the origin of these secondary fibres or fibrillæ to tiny granules of fibroin found isolated in the mass of sericin in the seritteri or glands, which are lengthened out during the emission of the silk, forming filaments parallel to the principal thread.

The section of the fibroin shows irregular forms most frequently resembling a triangle, with slightly curved sides.

Besides this, the silk, when stripped by means of suitable methods of its external wrapping of sericin, presents other irregularities of structure which must be mentioned.

The striations (channelling or stripiness) of the silk and its subdivision into fibrillæ of less diameter, which are sometimes found after degumming, can always be produced by suitable chemical and mechanical means, and for this it is necessary to remember that the thread of fibroin is not absolutely or uniformly cylindrical, nor in one homogeneous mass, amorphous and continuous, as some have asserted, but that instead it may be, in its turn, formed of very numerous and very slender elementary filaments, which, in some cases and under the action of physical and chemical agents, can be separated, setting up in this way the defect of the fiocchetti or fibrillæ which we lament in the dyed silk.

Sometimes the nucleus of fibroin shows knubs, slubs, or swellings, produced by the unequal gathering together of silky matter, as shown in Plate 2.

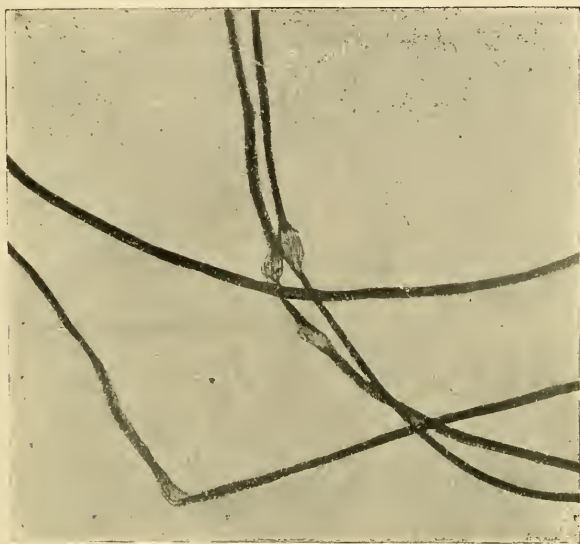


PLATE 2.

These knots or lumps, observed under a powerful microscope, very frequently present a streaked, ribbed, or channelled appearance, as shown in Plate 3.



PLATE 3.

It not rarely happens that, after degumming, these streaks or ribs on the thread show very plainly, so much so that one may sometimes find threads with longitudinal fissures, as seen in Plate 4.

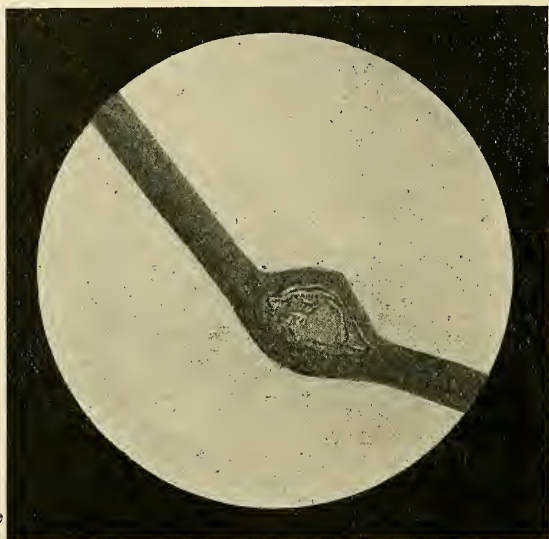


PLATE 4.

Sometimes a thread shows a kind of decortication, stripping, or peeling, as seen in Plate 5.

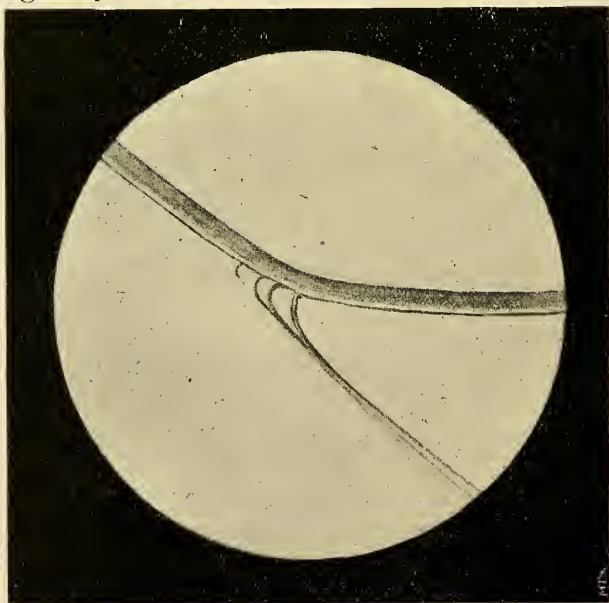


PLATE 5.

This fibrous structure of the silk, produced by the domestic silkworm, shown in an irrefutable manner in these later years, and especially in consequence of the studies of Italian naturalists, was for a long time a matter of controversy, and found determined opponents.

As far back as 1702 Leuwenhoek, after examining under the microscope the silk emitted from the silkworm, recognised that it was formed of two fibres or brins, and he was the first to discover that each one of these two fibres could in its turn be resolved into finer filaments.¹

This discovery is the more wonderful when one considers that the microscopical apparatus at the disposal of the great Dutchman was very imperfect, and that, in spite of the great improvement introduced in the microscope and its workings up to a few years ago, students were still divided into two entirely opposed camps on the question of the homogeneity of the silk fibre or brin.

Robinet, who towards 1838 used the microscope for its study, does not hint at any ribbiness or divisibility.

In 1839, Yules Bourcier and Poortman,² having examined the contents of the seritterio, saw the globules of silk matter lengthening as they passed through the excretory tube and the "filiera."

It is the lengthening of these globules, forming so many threads of the greatest tenacity, which explains the fibrous nature of the silk, and by it we can understand the tenacity of the thread.

Cornalia, in his classical monograph (1856), does not clearly explain his views on this subject.³ He says :

¹ Antonii A. Leuwenhoek.

Epistola data ad Serenissimum Illustrissimumque Principem Carolum Dei Gratia Hassiæ Landgravium, &c., &c.

Delfis Hollandonum XII. Kalendas Majas, 1702.

ARGUMENTUM.—Fila quæ a Bombicibus confici solent sunt duplicia atque a se invicem separari possunt; singula hæc fila iterum constant ex tenuibus filis.

Ego . . . fila recens ex Bombycum corporibus prodeuntia, microscopio opposui utpote mihi persuasi, singula fila ex Bombicina tele esse duplicia. Hisce meis observationibus nondum contentus cogitare coepi, an non tale filum simplex etiam ex pluribus filis tenuioribus conflatum foret, an tandem filum hæc tenue in varia minutissima fragmenta separavi, quando mihi apparuere variae tenuissimæ fibræ, atque visum mihi fuit tenuia hæc fila ex plurimis filis tenuioribus composita esse.

² Annales de la Société Sericicole, 1839.

³ Cornalia. Pamphlet on the Bombica of the Mulberry, 186, page 250.

"Under a rather powerful microscope the silk fibre is seen striped in its length, which is perhaps owing to its origin, the thread being produced by the stretching of the silky matter"; but he seems to treat of striations observed on the surface of the raw-silk; yet in a very clear illustration annexed to the text,¹ the author shows the nucleus of fibroin sub-divided into very fine fibrillæ.

In 1867 Ad. Targioni Tozzetti examined the silk of about twenty kinds of silkworms, and the result of his observations was that the thread of the *Bombyx Mori*, towards the interior part of the cocoon, becomes flat and stripey, whilst the thread of the *Antheræa Assama* or Muga silk (a wild silk) is ribbed or striped in the first reeled portions of the cocoon.

Similar results were arrived at in 1876 by Dr. G. Bidie, of Madras, and microscopic examination of the Wild Silks of India, China, and Japan, in 1879, by Sir Thomas Wardle, proved this ribbiness and fibrillæ structure, as shown in the illustrations in his "Wild Silks of India."

In 1869 E. Verson² showed that the fibroin contained in the seritteri of the silkworm could be artificially streaked or striped in its length by means of stretching, and could then be separated into innumerable fibrillæ by treating it with potash at 30 per cent, like the silk of *Antheræa Yama Mai* and of *Antheræa Pernyi*.

Nevertheless, in 1873 Dr. R. Schlesinger³ describes the brin of the *Bombyx Mori* as generally lacking in particular characteristics, but admits that one often observes longitudinal lines on it, and that with chromic acid the thread gains quite a ribbed appearance.

Persoz, in 1878, describes the characteristics of the thread of the *Bombyx Mori*,⁴ qualifying it as "full, thick,

¹ Table X., Figure 157.

² *Intorno alla nuova proprietà fisica della seta-Sericoltura Austriaca*. 1869.

³ *Mikroskopische untersuchungen der Gespinnst-fasern*. Von Dott Robert Schlesinger, Zurich.

⁴ J. Persoz. *Essai sur le conditionnement de la soie*, page 39.

and continuous, of a perfectly homogeneous constitution, and, except for the diminution of its diameter—which is, however, very gradual—it resembles the regular product from the reeling machine.”

In 1885 Rondot,¹ and in 1887 Duseigneur-Kleber,² both held that the silk thread was of perfectly homogeneous structure.

In 1888 Dr. Anderlini³ discovered “that the ribbing or striations can be seen in all the strata, even to those on the surface, by simply softening the gluten with steam or in any other way whatever; by which means, the gluten being detached and leaving bare the central parts of the fibre, this appears longitudinally ribbed, lightly certainly, but quite evidently.”

The same author shows another method suitable for demonstrating the ribbing of the thread, which consists of treating the silk with chloric acid, diluted, for eight or ten hours at 70 deg. Cen.; then to colour it with very strong mercurial salt, and to crush it with a hammer upon a steel anvil. The appearance of the fracture resembles that of a broken cord, or certain fibrous woods very much pulled to pieces.

In 1887 Dr. Franz Ritter von Höhnel⁴ recognised, like Schlesinger, that the ribbing can be developed by treating the fibre with chromic acid.

In 1889 L. Blanc⁵ declared that he had not succeeded, after many trials, in obtaining the results described by Verson in 1869, changing the fibre, the temperature, and the duration of the action of the alkaline solution. He declared besides that the experiments carried out by Anderlini, being executed by a too energetic method, are

¹ N. Rondot. *L'Art de la soie*.

² Duseigneur-Kleber. *Le Cocon*.

³ Bollettino mensile di bachicoltura. 1888.

⁴ Franz Ritter von Höhnel. *Die mikroskopie der technische verwendeten faserstoffe*.

⁵ L. Blanc. *Etude sur la sécretion de la soie et la structure du brin, et de la bave dans le Bombyx Mori*. (Laboratoire d'études de la soie de Lyon. Rapport 1887-88, Anno 1889.)

not trustworthy, and only prove one thing—that is, that the silk can be broken up by a hammer throughout its length. Still, he allowed that the surface of the silk thread, denuded of the sericin, is not absolutely smooth, but lightly streaked longitudinally. These ribbings would be, however, most superficial, and their origin would be purely mechanical—that is, owing to the stretching of the thread, in the same way that one sees the ribbings on threads of glass. He maintains also that the thread of the *Bombyx Mori* is perfectly homogeneous, and that the fibre forms a compact whole.¹

In 1890 Verson sent to Blanc some silk threads prepared under the microscope, in which were shown the striation and the separation into fibrillæ.

Blanc, following up the examination of these preparations, confessed that he had fallen into error in doubting the results of perfectly reliable experiments.²

In 1895 Professor Vlacovich,³ studying the vacuole, where the silky matter occurs in the interior of the seritteri of the silkworm, said he did not think the conjecture probable that was brought forward by Quajat, to the effect that the vacuoles are caused by tiny drops of sericin which have penetrated into the fibroin.

According to this author, the difference between the ribbing of the brin of the domestic silkworm and that of the wild silkworm would have its origin in the fact that in the latter the little channellings which are formed after evaporation of the water contained in the substance that forms the vacuoles are re-filled with air, while in the thread of the domestic silkworm the striations remain full of a special matter. He denies that the ribbed appearance of the silk thread may be caused by superficial wrinklins of the exterior of the nucleus of the fibroin, and admits a physical and chemical difference

¹ Ibidem, page 87.

² Bollettino mensile di Bachicoltura. 1890. N. 4.

³ Bollettino mensile di Bachicoltura. 1895. N. 1.

between the matter constituting the vacuole and that of the nucleus of the fibre. He recognised that alkalies render the ribbings evident in the places where they are less marked, as well as in the more exterior strata of the cocoon. He recognises likewise that the ribbings are shown by artificially drawing out the thread under water, and keeping it soaked in water during one or two days. This thread, treated with soda or potash at 2 per cent, is seen completely divided into very fine filaments, some of which, in their turn, show very clearly longitudinal ribbings. The ribbing can even be made to appear by mechanical means—that is, by the scraping of the thread.

In 1896 Professor Lenticchia, in a micrographic study of these *flocchetti* (that is, the excrescences in the fibre where the divisions occur) on the dyed silks, showed that it is possible¹ to obtain the ribbing on the thread of the *Bombyx Mori* by following the method used by Sir Thomas Wardle in 1879² to separate into *fibrillæ* the thread of the *Saturniidæ*—that is, by the action of permanganate of potash. He established the relationship existing between the ribbing and the unfolding or the separation of the thread into *sfaldatura* or *fibrillæ*. He recognised that it is possible to obtain the ribbing and the dividing of the thread by simply scraping it, as Vlacovich had done already; and he (Lenticchia) affirmed that the flat threads, more likely to separate during the operations of degumming and dyeing, probably owe their origin to the hurtful action of the fumigations to which the worms have been exposed during their rearing, the system of doing this having deteriorated.

The same Author,³ examining under the microscope the section of fibre which distinctly presented the ribbing or striations, discovers that the outer ring of sericin and the points corresponding to the section of the ribbings,

¹ Bollettino di Sericoltura. 1896.

² Wardle. The Wild Silks of India. 1881.

³ Rendiconto dell'Istituto Lombardo. Vol. XXXI.

act in the same manner by reflected light ; besides which some colouring materials, such as the gentian blue, dye equally the sericin and these points, and a solution of potash, cold, dissolves them both. Thus he concludes, on the basis of these experiments, that the striations are due to very minute fibrillæ of sericin. The disjoining of the fibrillæ during the processes of dyeing would thus be owing to the separation of the little interior threads of sericin. But all the threads do not show the streakings in an equally marked manner.

The same Author says that in the silk produced by worms that are weak from birth, or that are weakened by fumigation or from other causes during their rearing, the thread may be seen in ribbon form from the first layer of the cocoon, and with a great tendency to sub-divide into fibrillæ.

In 1904 Dr. Quajat,¹ in studying the action of alkalies for artificially producing the ribbing or dividing of the silk fibre, found that hydrate of sodium acts more energetically than hydrate of potassium ; and yet in 1904 Signor Conte and Dott. Levrat² recognised that diluted hydrochloric acid caused the thread to swell, and at the same time made the ribbing clearly apparent ; if, after about a quarter of an hour, the thread is pressed upon a "copri-oggetti" or other flat surface, the separation of the thread into numerous fibrillæ is obtained.

Chloride of zinc in a solution of medium concentration, acetic acid, and the liquid of Schweitzer act in the same manner, as well as the ordinary alkaline solutions. Of particular importance is the fact that with these processes one succeeds in producing evidence of the fibrous structure of all silks, and a similar result is obtained by treating with soda and compressing between two plates (or copri-oggetti) the thread drawn out by stretching the seritterio.

¹ E. Quajat. Dei bozzoli più pregevoli che preparano i lepidotteri setiferi.

² Laboratoire d'études de la Soie de Lyon. Vol. XI. 1901-2.

The Authors, while abstaining from expressing a definite judgment, hold that the tendency of the brin to split up or divide (*sfilacciarsi*) may be an inherent defect of the silk, and that the manipulations in the dyeing only make this tendency evident.

From the Works that we have passed in review, it appears that the merit of the idea of the possibility of the sub-division of the silk fibre into elementary fibrillæ, proved scientifically in these latter years, is due principally to the Italian and English microscopists and physiologists.



CHAPTER II.

All kinds of silk fibres are liable to what is termed by the Italian savants "Sfaldarsi," which means the splitting-up of the ultimate fibre or brin of the silkworm into fibrillæ, or very fine filaments. How the greater or less tendency of the silk to divisibility can be explained: Influence of the selection of species; of the manner in which they are cultivated; of the diseases caused by fumigation; of degumming; and of the dyeing and mechanical operations.

ALTHOUGH in the elementary fibre or brin of the *Bombyx Mori* the longitudinal ribbings, which are characteristic of the greater part of the wild silks, are not always apparent, the fibres of the *Antheræa Mylitta*, *A. Pernyi*, *A. Assama*, *A. Yama-mai*, *Philosamia Cynthia*, *Actias Selene*, *Attacus Atlas*, &c., are all microscopically visibly ribbed, as shown in Plate 6.

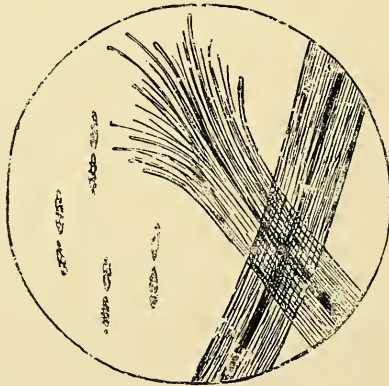


PLATE 6.

FIBRE OF ANTHÆA MYLITTA, WITH THE FIBRILLÆ DIVIDED,
BY SIR THOMAS WARDLE.

This plate is taken from Sir T. Wardle's Monograph.

It will be seen, nevertheless, from the works passed in review in the preceding chapter, that all are formed of a bundle of threads placed parallel and longitudinally one beside the other, and all solidly united so as to appear one homogeneous fibre or brin. The fibrous structure of the nucleus of fibroin cannot, in fact, be verified as long as the fibre retains its coat of sericin, which is a peculiarity of the raw-silk, and which is only set free when, with a solution of soap, either hot or cold, one succeeds in loosening the bed of colloid material, which, among its other functions, has that of preserving the thread from contingent damage or lesions and of preventing, from the formation of the cocoon to its unwinding, the thread from fibrillæ divisions. From this we can understand that the industrial researches with which we are occupied affect only the silks in process of manufacture, and not the raw-silks, since the disintegration of the fibres cannot be verified unless it is preceded by degumming, and by the solution of the substance which cements and envelops the two adjoining single filaments or brins.

In reflecting on the manner in which the fiocchetti or tangled excrescences are formed, it is evident that there can be no relation whatever between the defects studied in our work on the ordinary silks of Lombardy¹ and those which are derived from the sfaldarsi or splitting-up of the fibre, since the knots, loops, duvet, bouchons, and portions of loose straggling fibres, as well as those lying about and not cemented in any tangled threads of the raw-silks, have nothing to do with the internal structure of the fibre, having their origin in the carelessness or want of skill of the reelers, whilst the fiocchetti much more specially, as we shall see afterwards, come into the departments of the cultivator and the dyer, and are connected with the structure of the ultimate fibre or brin.

For the reasons given above, one cannot credit those who affirm that they have met with these tangled fibrillæ

¹ The Milan Chemical Society's Annual Meeting, 21st April, 1900.

in the raw-silk, since the *fiocchetti* or excrescences produced are formed from filaments whose diameter descends as low as 2 micromillimetres, whilst the fibre of the ordinary silkworm has a diameter of not less than 10—12 micromillimetres.

The five illustrations shown below give an idea of the difference between the nibs or tangles of the ungummed fibres of raw-silk, known as *duvet* and *bouchons*,

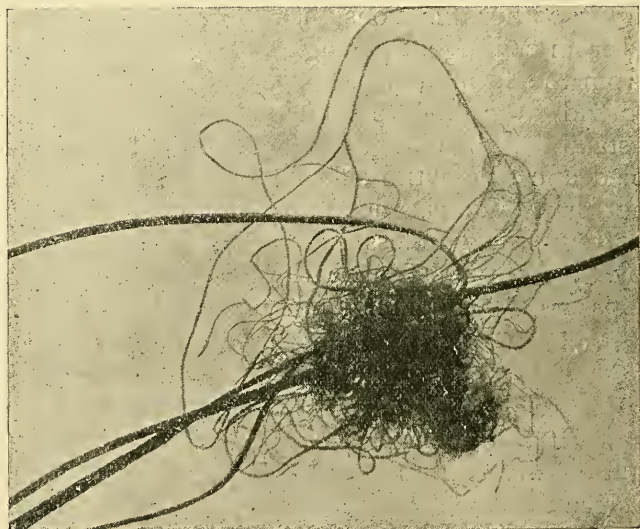


PLATE 7.

BUNCHES OF FIBRILLÆ IN THE BRIN OF DEGUMMED SILK.

and of the *sfaldatura* or ravelled and divided fibrillæ of the brin. (See Plates 7 to 11.)

Also the internal section or axis is not absolutely regular. Blanc, in 1866, tells us that he had observed, with regard to the issue of the fibroin, that some thin straggling filaments were parallel to it.

We believe the assertion, first upheld by Professor

Lenticchia, to be equally unfounded, which gave credence to the opinion of a dyer of Como, that the silks produced by Italian cultivators are more liable to *sfaldarsi* or splitting than those of other countries.¹

On this question the fact is not without interest that the microscopical examination of several silk tissues which have been procured for us, dating from some centuries ago, does not result in an appreciable number of *fiocchetti*,

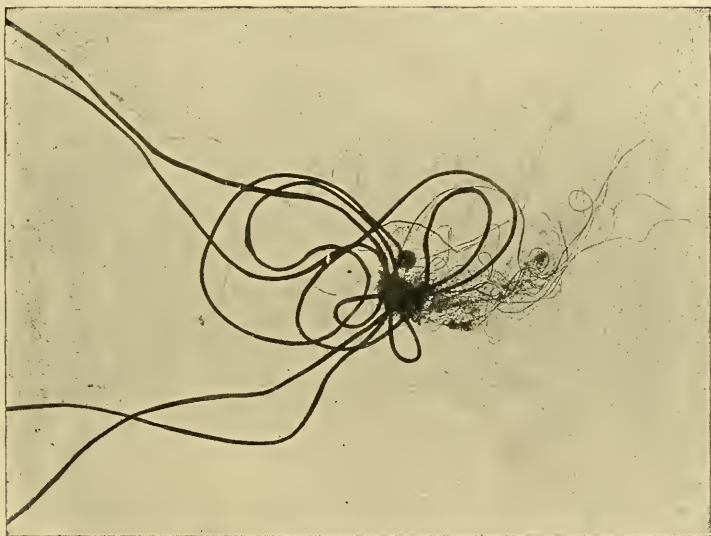
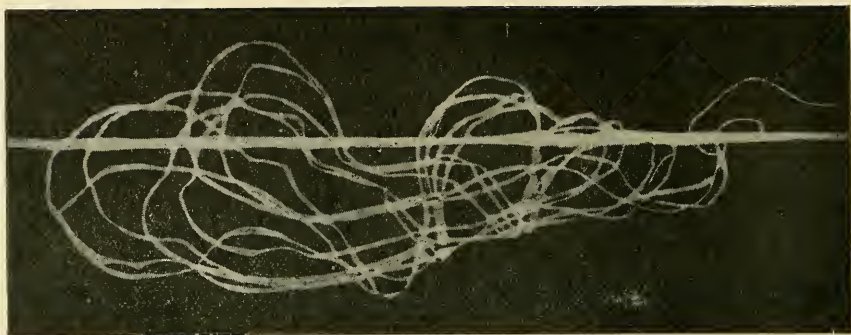


PLATE 8.

BUNCHES OF FIBRILLÆ IN THE BRIN OF DEGUMMED SILK.

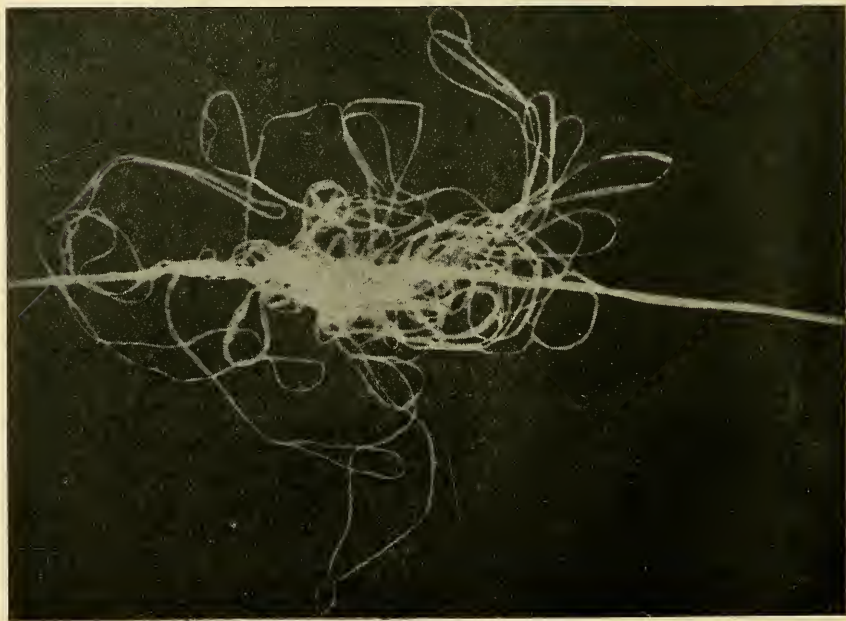
sfaldarsi, or divided filaments or fibrillæ of the brin, called knots, knibs, also flocons, pelotons, and, in America, lousiness and ravellings; and as concerns the

¹This was confirmed by Sig. Sisley, who has declared as follows: The opinion expressed by Professor Lenticchia, and according to which this defect would not be met with in Asiatic silks, is not correct, for we have found certain qualities of silks of Japanese origin which yielded very easily to this defect.



DUVET.—PLATE 9.

SLUBS, KNIbbINESS, RAVELLINGS, AND IN FRANCE TERMED DUVET AND BOUCHONS, OF THE RAW-SILK FIBRE BEFORE THE SERICIN-IS DISCHARGED.



BOUCHON.—PLATE 10.

influence that the conditions of rearing may afterwards have exercised, these being mitigated by the increase of knowledge in the science of bacology (sericulture), the doubt that the cultivators of the present day have no regard for the quality of the cocoons, or that they merit reproach with regard to the selection of stock, does not

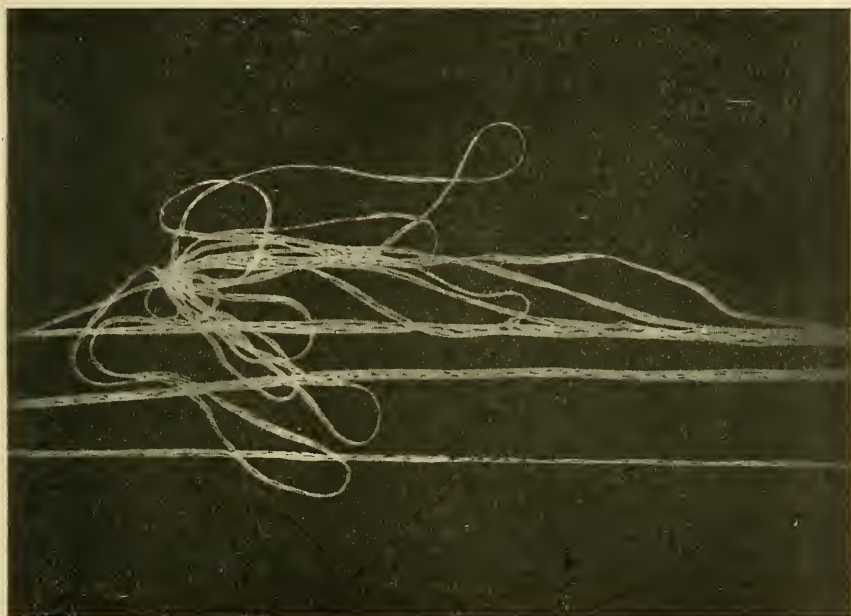


PLATE II.

SLUBS, KNIBBINESS, RAVELLINGS OF BAVE AND BRIN, AND IN FRANCE TERMED DUVET AND BOUCHONS, OF THE RAW-SILK FIBRE BEFORE THE SERICIN IS DISCHARGED.

seem to be justified, even admitting the inferior quality of the Italian silks in comparison with the foreign silk, and we do not for a moment believe the accusation.

But it was important to ascertain whether the species cultivated at the present day might present a less resist-

ance with regard to the "sfaldabilita," or liability of the threads to divide into fibrillæ, and whether in succeeding years the chief aim of research had not been directed to productivity rather than to the quality of the cocoons. To clear up this point the Commission of Works on Silk caused the cocoons of the principal species cultivated in Italy, pure as well as crossed, to be examined, and their researches on the products of the cultivation of 1895-6 did not in any way prove that the Italian silks present a greater tendency to sfaldabilita in the dyeing operations.¹

Especially in the tests for winding the degummed fibres, an operation which reveals the abnormality of the structure, one had not to verify sensible variations, and the fact is worthy of note that the breakages for every 1,000 metres vary from 0·5 with a maximum of 8 in the first 20 specimens of cocoons which we have examined, and between 3 and 4 for the 16 successive specimens, whilst in the threads drawn from cocoons from the six Chinese provinces are found a minimum of breakages of 2·1 and a maximum of 6·7 per 1,000 metres.

Having had in this manner new confirmation of the superior quality of Italian silks on a numerous series of specimens produced from divers sources, which were degummed and dyed under the same conditions, we now proceed to the tabular enumeration of the fiocchetti, extending our observations to some wild silks, altogether amounting to 52,200 metres.

¹ Laboratory for experimenting on silk. Analyses and researches carried out from 1895—1898, pages 25 et seq.

FOREIGN SILK.	Silk Boiled-off and Dyed in a Dyehouse.	Silk Boiled-off and Dyed in the Laboratory.	Average.
	No. of Fiocchetti per 1,000 m.		
Cevennes	85	90	87.5
Japan.....	179	164	171.5
Bagdad.....	114	152	133
Broussa.....	249	155	202
ITALIAN SILK.			
Incrocio Chinese	77	144	110.5
Brianza extra	194	142	168
Yellow Brianza	66	190	128
Bassa Lombardy	83	93	90.5
Class Lecco.....	47	80	63.5
Class Bergamo	194	99	146.5
Bresciana	78	69	73.5
Piedmont	61	190	125.5
Astigiana	61	63	62
Friuli classica	47	80	63.5
Friuli.....	39	72	55.5

This list shows that the medium number of fiocchetti found after the degumming on 16,200 m. of foreign raw silks amounted to 142 for every 1,000 metres, whilst in those of Italian production, after examining 36,000 metres, it was only 97 per 1,000 metres; and by also taking into account the variations verified by means of results obtained from silks degummed and dyed in the laboratory and in industrial establishments, we find that the minimum number of fiocchetti met with in Italian and foreign silks was respectively 55 and 87, and the maximum number 168 and 202.

This proves, then, that the Italian silks are not found to be inferior to the foreign ones; in all are seen noteworthy differences in the number of *flocchetti*, which denote the irregularity of recurrence of the defect, equally in the case where the degumming is done with the greatest care in the laboratory as in that in which it is done by the operative dyer in his dyehouse.

The major or minor tendency to *sfaldarsi*, or splitting, that silks of a like origin present, ought not to cause surprise when one reflects on the great variety of races of silkworms and crossings of breeds that are cultivated and raised at the present time, and on the sensibility of the silkworms to changes of diet, to the modifications induced by the conditions of rearing, and especially to the degree of selection, more or less perfect, to which they are subjected.

It will suffice to record the variations that are found in the self-same sample with regard to sericin and fibroin in the diameter and the length of the threads, and the abnormality shown by the microscope when a few kilometres of bave are passed across the limelight projection.

Since many wild silks show the ribbing or striations more clearly and are more especially subject to *sfaldarsi*, it is logical to suppose that, according to the antiquity and the better selection of the cultivated species, the tendency to divide into *fibrillæ* will be less; and, in fact, this deduction accords with the result of our researches, which show the superiority of our Italian species and of Chinese cross breedings, and which also confirm the observations of A. Rosenzweig,¹ according to whom the "*sfaldatura*" or divisions are met with more frequently in the Levantine silks, which come from regions in which the cultivated species are the product of a less accurate selection, and which do not go back to so distant an epoch. For this reason silk cultivation according to the foreign manner, which is conducted with less care than

¹ A. Rosenzweig. *Serivalor*. Wien, 1904. Page 53.

with us, is not desirable, a fact which is confirmed also by the poorer yielding ("reddito") of the cocoons, which ordinarily varies about from kg. 28-30 to an ounce of seed.

With regard to the Italian silks, the fact is that when we endeavour by artificial means to induce the splitting up of the brin by exaggerating the treatment used in the dyeing, only in very rare cases have we succeeded in causing a sufficient number of fiocchetti to appear in the fibres as would sensibly depreciate the value of the woven tissue. The few specimens liable to be easily divided into fibrillæ which were shown to us came chiefly from the cocoons of the Levant, and are a proof that the species cultivated at the present time in Italy are sensibly weakened. According to us, the irregularity of the defect (*saltuarietà*) may find a more plausible explanation in the tendency to return to atavistic forms—*i.e.*, to the character of the wild silks—a tendency seen with not less frequency in other fields of animal life.¹

The infiltration of sericin in the bundle of fibrillæ which constitutes the brin, observed by Verson, and to which Lenticchia attributes its tendency to divide into fibrillæ (*sfaldarsi*), might also be a consequence of the pathological state of some silkworms, if we consider the rarity of the cases in which the phenomenon is seen.

But whilst not wishing to deny that the constitution of the silk thread can in many ways be influenced by bad treatment, and by the unfavourable conditions under which the silkworms are sometimes cultivated, the experiments we have repeatedly carried out in these later years show that, with regard to the races cultivated in Italy, the treatment for causing "*sfaldatura*" of the fibres results in the latter being present in a small measure—smaller than could have been supposed.

¹ We meet with a well-known example of a return to atavism in the cocoons obtained from crossings, in which the return to atavistic characteristics is very frequent with regard to form, colour, &c.

Passing thus in review the causes of the greater or less dividing into fibrillæ (sfaldatura), following up the observations of Targioni Tozzetti in a preceding work,¹ we have brought forward the supposition that the fiocchetti are more frequently seen in silk that is produced from cocoon-reeling, in which the drawing-out of the bave is pushed to such an extent as almost entirely to strip the chrysalis, and we are guided to this conclusion by the consideration that the last pieces of brin that the silk-worm emits, being in ribbon forms, would be more disposed to divide in fibrillæ.

Having separately gathered the first and last portions of the baves of a parcel of yellow cocoons from Salonica, and subjected them to degumming and to dyeing under conditions exactly similar to those practised in the dyeing trade, the enumeration of the sfaldatura gave the following results:—

	Number of sfaldatura per 1,000 metres.	
	Specimen 1.	Specimen 2.
Silk from outer layers of cocoon.....	77	50
Silk from inner layers of cocoon.....	61	58

As one sees, the fibres from the external parts and those from the last internal parts that can be utilised do not always present any remarkable difference, even when they come from Levantine cocoons, and this deduction can justly be extended to the Italian cocoons, which, as we saw, gave on the whole an inferior number of fiocchetti.

But we entertained a doubt as to whether the silks drawn from cocoons obtained from worms affected by botrite bassiana, or muscardine, might not present less resistance to the degumming and dyeing operations, and to clear up this point we have placed under treatment a bundle of cocoons, of which a part had been attacked by this disease.

After degumming and dyeing the raw thread obtained, we met with the following number of fiocchetti:—

¹ Pamphlet on Sericulture, 1900, page 439.

Length of thread examined, 1,000 metres.	Sfaldatura per 1,000 metres.	
	Specimen 1.	Specimen 2.
Silk from cocoons not diseased	58	81
Silk from cocoons so diseased.....	39	58

The differences are quite insignificant, and do not exceed those found in examining different portions of bave from one specimen, so that we must exclude any correlation between the course of the botrite disease and the tendency, more or less, to divide during dyeing.

Also as concerning the effect of fumigation, the results were not alway conclusive, since the silks obtained from the rearing of Chinese crossing, carried out in 1902, in industrial comparison, as much with fumigations of sulphur as with those of formaline,¹ do not show an unusual number of fiocchetti as compared with those obtained from a rearing under ordinary conditions, and, in fact, they showed the following results :—

Silk in comparison, length of thread examined 6,000 metres.	Number of sfaldatura per 1,000 metres.
Silk from cocoons, with fumigations of sulphur	189
Silk from cocoons, with fumigations of formaline	186
	207

While it was averred that the fumigations cause the weight of the cocoons to diminish when they are thoroughly applied, and that they have an unfavourable influence on the rendement or yield of silk, no abnormality was remarked as regards the sfaldabilita or exfoliation; it is probable, nevertheless, that to these results the fact already shown by Professor Verson may have contributed—*i.e.*, that the selection of the less perfect threads may be owing to the ignorance of the reeler during the “throwing,” as the less yield of silk thread makes evident.

The contradictory results obtained by Professor Lenticchia on the silk produced by a cultivation of 75 cocoons, no less than those obtained by us from a rearing made within small rooms, may find an explanation not only in the variety of the species and of the cultivated

¹ Pamphlet on Sericulture, 1902, page 372.

crossings, but also in that he had studied the thread reeled with all the care of a laboratory experiment.

Neither can it be forgotten that the greater sensibility met with corresponds exactly to sporadic cases of return to wild forms, while the greater number of *fiocchetti* is owing to the manner in which the degumming is carried out.

What gives reason to this conjecture is the fact that the defect of *sfaldarsi* has been met with, as has been already said, more especially in the Levantine silks, from the regions, that is, in which the practice of fumigation is unknown.

Also the doubt remains whether the conditions under which the rearing of the silkworms are carried out—that is, the greater or less ventilation, the dampness and the temperature—may not influence the quality of the silk; and that is why, in the campaign of 1902, two rearing experiments were carried out with species obtained from a Chinese crossing, white female (*feminina bianca*), the first in premises well ventilated, in which the temperature was maintained at 24 deg. to 25 deg. Cen. and relative dampness to 59 per cent, the second in a non-ventilated place at 29 deg. Cen. and 91 per cent humidity.

The *rendement* or yield in cocoons was kg. 60 in the first case, and kg. 19.5 in the second for every ounce of seed, the flaccidity having developed. The threads obtained after degumming and dyeing showed the following number of *fiocchetti* on 17,000 metres of thread examined in every specimen:—

	1.	2.	2.
Ventilated rearing, <i>fiocchetti</i> 1,000 m.....	280 ...	147 ...	208
Non-ventilated rearing, <i>fiocchetti</i> 1,000 m....	183 ...	100 ...	113

Even in this case one cannot affirm that the quality of the silk is essentially deteriorated by sickness and damp, for the reason that the threads drawn from the cocoons on which one could experiment probably represented those of the greatest resisting power in the cultivation.

Among the operations to which the silk is subjected, in order to acquire the splendour and the delicacy which are characteristics of this fibre, must be considered the degumming, since the variations observed in the number of fiocchetti depend in a great measure on the manner in which this is carried out.

It will suffice to state that the number of fiocchetti met with in 22 specimens of threads degummed and dyed by silk dyers exceeds by 77 per cent those observed on the same threads dyed in our laboratory under ordinary conditions. In fact, the medium result deduced from observations on 70,000 metres of thread was as follows:—

	Fiocchetti.
Threads degummed and dyed in laboratory	216
Threads degummed and dyed by silk dyers	986

One of the cases which specially deserves to be mentioned is concerning a silk which came from a United States dyehouse, which showed 2,439 fiocchetti for every 1,000 metres, while some skeins taken from that bundle and degummed and dyed by us gave—

Fiocchetti..... 230, 219, 250, 203 per 1,000 metres.

In taking into account the different factors that act upon the defect pointed out, we must, above all, remember that, given the dissociability of the soap and the solvent action that alkalies exercise on albuminous matter, it must be expected that the sfaldatura of the threads would be facilitated by excessively prolonging the degumming.¹ In fact, having subjected to repeated boilings-off or degumming (cottura), in a 3 per cent soap

¹ Sig. Sisley, in the communications he has so kindly imparted to us on this subject, attributes the different colourings that the denuded fibrillæ assume to a chemical alteration caused by the alkaline baths, which would manifest itself in a different affinity for the colouring materials. This would be shown by the fact that in alkaline baths of alkaline blue and benzoporporina the slubs take a light red colour, whilst the silk is blue.

Having dyed in the above-named bath a skein of degummed silk, on comparing it with another, also degummed, but which had suffered the action of caustic soda, we observed that this last had assumed a more intense blue colour, and hence we believe that the red colouring of the slubs may be owing to a physical phenomenon.

bath, a silk with a special tendency to sfaldarsi, there appeared the following results:—

	1.	2.
Simple degumming, fiocchetti.....	155 ...	110
Double degumming, fiocchetti.....	559 ...	474

By employing a somewhat alkaline soap containing 0.5 per cent of free NaOH, the number of slubs, specks, etc. (fiocchetti) became—

With two soap baths	560 per 1,000 m.
With three soap baths	910 per 1,000 m.
With four soap baths.....	5,540 per 1,000 m.

The influence that the duration of the degumming exercises is rendered specially manifest in silks that have to be dyed in light colours, and for that reason need a more perfect cleansing or bleaching (candeggio).

An organzine, which degummed in the laboratory gave 675 microscopic excrescences, slubs or specks (fiocchetti), dyed white by a dyer showed 1,852, whilst after being degummed (boiled-off) to be dyed blue, only gave 182. Under the same conditions, a tram that gave 752 fiocchetti when dyed in pale colours, showed only 323 when dyed blue.

Also, the presence of an excessive quantity of sericin in the soap bath—*i.e.*, the system of utilising the baths remaining from preceding degumming—would, according to G. Von Georgievics, cause the formation of the balls, slubs, or specks, &c. (fiocchetti).¹ In fact, having degummed a tram in a specially prepared soap bath during 15 minutes, we have found thereon 116 fiocchetti, whilst on employing an old bath the number became 247, because the boiling had to be prolonged for an hour and a half.

The mechanical operations also exercise a remarkable influence, especially the stretching of the threads after they have imbibed the soap. A yellow organzine kept for an hour in a soap bath at 3 per cent, and

¹ Lehrbuch der chemischen Technologie der Gespinnfasern, 1898, II., page 35.

subjected to stretching corresponding to 5 per cent of the length after the first half hour, and to 12 per cent after the second, showed 775 excrescences for every 1,000 metres, while it only gave 152 when kept quite still in the same boiling bath during six hours.

Reflecting on the fact that the fraying or ravelling shows more particularly on the tram in which the threads are for the most part free, in comparison with the organzines which are twisted, the doubt arises whether an important part should not be attributed to the actions, mechanical yet light, which are exercised on the silk during the degumming, especially because the silk when saturated with soap shows less resistance under heat.

This conjecture has found abundant confirmation in the degumming tests, so carried out that the fibre is not subjected to any movement, both by preventing the bath from boiling or by winding the silk on special bobbins with permeable cover. The results obtained were as follows :—

	Silks.	
	Raw.	Organzine.
Degumming by boiling in a free bath, followed by ¹ “Chevillage,” fiocchetti.....	1,254	... 196
Degumming in a bain marie, in a motionless bath, fiocchetti.....	649	... 112
Degumming in a bain marie, on bobbins, fiocchetti.....	16	... 22

These results have been confirmed in a further test on a raw-silk that had given rise to discussion, from which the following results were obtained :—

	Fiocchetti per 1,000 metres.
Specimen degummed and dyed in a foreign dyehouse.....	1,251
Specimen degummed and dyed at home.....	1,103
Specimen degummed in laboratory by usual processes.....	905
Specimens degummed on bobbins and afterwards dyed	33

Thus we see that the number of balls, slubs, or specks (fiocchetti) is reduced to insignificant proportions when the silk is not subjected to any strain, and it seems

¹ What is known in the dyehouse as “sticking up” the silk and preparing it for dyeing.

as if we may attribute this to the great ductility that the silk acquires when it is immersed in a boiling bath of soap, as is seen from the fact that it becomes susceptible of greatly extending its length and of structural changes.

From these explanations it is easily understood that, besides the degumming, the dyeing manipulations, and especially the treatment to which the silk is subjected for the weighting and lustreing, cannot be without influence.

The following table shows the results obtained from some specimens of silk subjected to several treatments with tin salt, and afterwards weighted and dyed by us, by an American dyehouse, and by one in Lombardy :—

	Length Examined, 10,800 metres.	Slubs per 1,000 metres.
Silks dyed and weighted in America	12,979	1,201
Silks dyed in laboratory without increase of weight	1,007	92
Silks dyed by a laboratory dyer	1,025	95
Silks dyed in laboratory and weighted with SnCl ₄ , fixed with carbonate of soda	921	85
Silks dyed in laboratory and weighted with SnCl ₄ , fixed with phosphate of soda	1,581	165

As might be foreseen, the results were not less manifest in dyeing black. Having sent some skeins from a bundle of white tram to some of the principal European dyeworks to be dyed in heavy black, the examination of the thread after dyeing showed the following results .—

	Increase of Weight per cent.	Number of Slubs per 1,000 ms.
Silk degummed	—	110
Silk dyed in Switzerland	69.4	582
Silk dyed in France.....	78.6	385
Silk dyed in Italy.....	42.8	579
Silk dyed in Germany.....	100.0	400

The experiments that we have brought forward show that the conditions of rearing, the fumigations, and the diseases to which the worms are subject, do not exercise any great influence on this defect when experimenting on well-selected species, and on threads obtained in industrial proportions; they also prove that the slubs

or balls are found in degummed silks coming from every source. Thus the result is demonstrated that the greatest variations noticed must be attributed to the dyehouse operations, since one and the same specimen of silk presents such important differences in the number of split up or divided fibrillæ, according to the knowledge of the dyer as to proportioning his treatment to the resistance of the silk thread.



CHAPTER III.

Limits within which the defect of fiocchetti is confined ; proportion of fiocchetti, demonstrated by various tests ; necessity for the manufacturer to be able to define the quality of the silk he buys ; the difficulties met with by the dyer in degumming, and the necessary equipment conditions for the most perfect boiling-off or degumming of the silk ; improvements introduced and consequent results ; Conclusion.

As has been previously shown, the formation of fiocchetti on the dyed silk is especially prejudicial, by reason of the lessened brilliancy that it causes in the tissues, which are depreciated in value according to the number of microscopical ravellings of fibrillæ that are found scattered on their surface.

Since, as has been seen, there are no silks quite immune from divided fibrillæ, and even the best show a number that varies from 10 to 100 for every 1,000 metres of thread, according to the method followed in the degumming, it is, therefore, comprehensible that the endeavour of the dyers should be directed to making this number remain within the limit which does not disfigure the appearance and lustre of the textiles.

Practice has shown that the presence of 100 to 150 fiocchetti for every 1,000 metres of threads used for the usual articles of manufacture does not hurt the appearance of the material to any sensible degree, and it is only when they amount to some hundreds that the effects become disastrous. As the success of many fabrics is dependent on the judicious selection of the raw-silk employed, and that it is not possible to distinguish by the exterior aspect of the raw-silk those which are capable of bearing the degumming and dyeing operations, and of furnishing tissues which present the desired results, there only remains for the manufacturer to have recourse to the

direct examination of a small portion, subjecting it to such tests as will permit him to assure himself of the good quality of the silk he proposes to use. Especially, if he concerns himself with the acquisition of silk of unknown origin, or in the production of new articles, it will be advisable always to make trials of degumming in two successive baths of soap at 3 per cent for the duration of half an hour, as is the practice in the official establishments for conditioning examination by boiling-off trials.¹ Dyeing should follow this operation in order to render the *fiocchetti* more perceptible, and so proceed to the necessary comparisons with threads and tissues of already known textiles.

For comparing different threads or tissues of an ascertained brightness, and for detecting *fiocchetti*, the operation can be facilitated by winding the threads on a little varnished board, placing one by the side of the other so as to cover a given portion of it. The apparatus that Messrs. Henry Baer and Co. have constructed for this purpose is shown in the accompanying illustration. (See Plate 12.)

Desiring to proceed to the enumeration of the *fiocchetti*, the manufacturer should act in the manner shown by P. Francezon for the detection of the defects of raw-silks, which consists in passing three or four threads to be examined over a little table of opaque black marble, unwinding them from bobbins at a variable speed, according to the skill of a workman with eyes specially trained to perceive abnormalities in the thread, and to distinguish the defects of reeling *sfaldatura* from those of the split-up or divided *fibrillæ*, and from those caused by entanglements in the fibre (*duvet* and *bouchons*). If unable to

¹ It is evident that silks which can bear the usual process of degumming, commonly known as boiling-off, will emerge from the operation still better when such an improved method as we shall describe further is applied. In the dyehouse the boiling-off is generally done at a temperature below 212, and with two consecutive soap baths, the first by using 30 to 33 per cent of soap per weight of silk, and the second with one half. For dark colours the second bath is not unfrequently used for the boiling-off of a subsequent lot.

find an experienced workman, he may have recourse to the projection apparatus, provided with accessories for winding and reeling the thread, according to the manner invented by Koristka, to change the speed at will.

The results obtained by examining the boiled-off threads by the above method with a microscope are not, however, comparable with those obtained by the naked eye, since, with the help of magnifying apparatus,

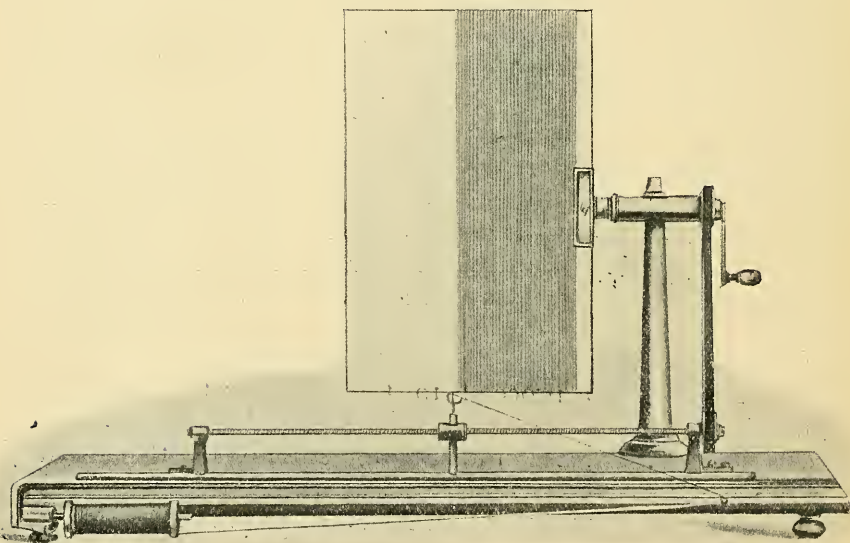


PLATE 12.

imperfections are visible that cannot be seen by the naked eye, and with which the manufacturer, acting only commercially, need not interest himself, as they have little influence on the commercial value of the textile.

With this view, he should not forget that the threads do not present a uniform structure, and for this reason the results have no value unless they are carried out on sufficiently long lengths.

In order to ascertain the variation to be seen in one particular quality of silk, we subjected a skein to degumming and dyeing, heated in a water-bath, and afterwards we numbered the fiocchetti on 16,000 metres. The results obtained prove that the number may be between a minimum of 42 and a maximum of 251 per 1,000 metres, when the comparison is limited to 500 metres. By extending our observations to 2,000 metres, the maximum variations, deduced from the comparison of results from four series of tests on 500 metres, were reduced to 53-119. In examining 4,000 metres it became 81 and 175; finally, with 8,000 metres, it became 107-158.

Besides this, in an extended number of observations it happens likewise that the tests shown have always been carried out on threads of the same titre and of the same twist, since, as might be expected, the threads in which the baves are less pressed one against the other, because of imperfect throwing, as often happens in the tram (weft), are in a condition to render the defect more manifest, in comparison with that seen in the organzine, which usually appears less defective. The manufacturers are consequently exposed to greater risks when occupied in the making of materials in which the tram is used to give effects in tissues in order to obtain additional lustre upon certain fabrics where the greatest brightness is essential.

In the tests directed to the discovery as to whether certain silks of known origin are more than usually subject to splitting or dividing, we must not neglect one factor which has an influence on the complete appraisal of this defect. This has its seat in the different colourings imparted to the silk, which change the degree in which the fiocchetti are visible. According as the tints penetrate more or less deeply into the nucleus of the fibre, and according to the intensity and nature of the coloured rays that the fibre reflects, the tangled fibrillæ appear more or less clearly. For this reason threads of

the same quality are seen to be unequally defective when, from light monochromatic tints, they pass perhaps to trichromatic. Wishing to ascertain to what extent the number of fiocchetti are visible in one thread, we dyed in our Laboratory, under conditions precisely identical, one quality of silk in the following colours, in order to compare them :—

	Number of Fiocchetti per 1,000 metres.
White silk thread	378
Yellow silk thread	481
Green silk thread	383
Red silk thread	356
Blue silk thread	264
Black silk thread.....	115

As we see, the fiocchetti are least visible when the silk is dyed black, and most visible in yellow ; and the observations of experienced buyers of silks, who affirm that yellowish browns are the colours which are most frequently hurtful, are in harmony with this result.

Even when the manufacturer has taken into account all the factors which act upon the brightness of the fabrics, and in relation to them has regulated the buying of the silks, the result is always subordinate to the work of the Dyer, who, in his turn, has no light difficulties to overcome, especially with regard to the operations of boiling-off and cleansing, in order to keep intact the brightness of the silk.

If the silk threads were always of the same nature, it would not be difficult to establish the conditions under which the degumming could be performed without giving rise to split-up or divided fibrillæ, but as they differ according to their quality, the degree of twisting, the manner of winding, and the stretching that they undergo, the work of the Dyer becomes very difficult. Having to work for third parties, he has no means of inquiring into the origin and state of the silks confided to him, and however conscious of the obligation incumbent upon him to sufficiently test the silks with opportune degumming trials, which would enable him to recognise the nature of

the silk and to classify it, with the object of modifying the degumming and cleansing of the parcel before proceeding with it in bulk, he can only be expected to take into consideration the general or commercial characteristics, which are very uncertain, and cannot always be observed or corroborated by serimetric tests, because these concern the multiple thread, and not the bave from which it is produced.

Also, supposing the Dyer to be acquainted with the quality of the silk that he daily received from the manufacturers, it would not always be possible for him to take into account all the factors that act on the result of the cleansing, not only because it is not easy to establish their existence, but also because in the present condition of the market the remuneration for the degumming and dyeing does not allow of his always keeping the different parcels separate, and of proportioning the duration of the boiling in the soap bath to the nature of the thread. In many cases he is obliged to treat in the same manner silks of poor quality, with little spin or throw, which suffer a loss of sericin of from 25 to 26 per cent, with others that lose in the same soap bath only 16 to 17 per cent of sericin or gum. Often, to facilitate the throwing, the silks have received special preparations of fats, which dissolve with difficulty in the soap baths, whether treated with mineral and saline substances, such as salts of tin, or with phosphates or with borate of soda, which tend to the fixing of earth salts.

In these cases the ordinary boiling-off is not sufficient, and more energetic treatment, which is hurtful to the quality of the silk, is rendered necessary. It ought not to cause surprise that to-day, more than in the past, the inconveniences owing to the system of boiling-off such silks promiscuously in concentrated and hot soap baths, are more noticeable. At one time the silk was degummed in large cauldrons, placing it in linen bags, which were moved about with a stick or pole, and in this primitive way, as long as our Italian silks took the lead in

our dyeworks, there were no such inconveniences to deplore; but after 1875, when the Levant silks became more abundant in the markets, it was necessary to have rectangular vessels, furnished with pipes for steam heating, in which to hang the silks on sticks, and to be able to limit the degumming according to the quality of the silk. If, from this side, the innovation was advantageous, it cannot be argued that it was also beneficial as regards the uniformity of heating, and the doubt is not without foundation that in many cases the differences observed in the number of fiocchetti between the silks degummed in industrial dyehouses, contrasted with those degummed in our laboratory, may have their origin in that the lengths nearest to the tubes undergo an excessive heating.

Taking the results obtained by degumming the silks without stirring them at all, we must remember that the process thought out in the first half of the last century by M. Michel di Lione for degumming the silks, described by Dumas in 1846 in his *Treatise on Practical Chemistry*, and which consists in subjecting the silks, saturated with a solution of soap, to the action of vapour in a hermetically closed receptacle, should obviate the stirring and stretching which the silk undergoes in the ordinary process, which is the cause of lamentable damage. But the application of this expedient, which was also the object of the English patent, No. 264, of Messrs. Fortier and Philippe, is defective, not only on account of the danger that the apparatus may explode, as some writers admit, but also because the silks lose their tenacity in a sensible degree as soon as they are exposed to a pressure superior to that of the atmosphere in the presence of soap. The following experiments show the influence exercised by the degree of heat in the bath, when prolonged for an hour in a soap solution of 3 per cent.

Average of 30 dynamometric trials:—

	In bain marie.		At 100 deg. Cen.		At 102 deg. Cen.		At 105 deg. Cen.		At 110 deg. Cen.	
Ductility...	100		98·8		94·1		93·6		88·5	
Tenacity...	100		96·6		94·2		93·5		85·5	

These results show the necessity of working, as far as possible, at a moderate temperature, and indeed in our tests the best results have always been obtained when the degumming was carried out in a bain marie, keeping the silk entirely submerged.

Under these conditions the degumming is completed at the end of an hour, and the number of the split or divided fibrillæ is notably inferior to that which we find in the ordinary boiling-off method, but the volume of the soap solution requisite is considerably greater than usual.

The Brothers Schmid, of Basle,¹ believe that they can bring about advantageous results by first softening the sericin by exposing the silk to the action of soap foam in boxes, at the bottom of which is found a solution of soap and two coiled tubes conveying air and vapour. The degumming is finished in the usual manner by hanging the silk on rods, which circulate by mechanical means. As it is not in the first phases of the boiling-off that one runs the risk of setting up the split or divided fibrillæ, we do not see the utility of this innovation, the results of which up to now have not found favour.

To sum up, it seems to us that the following are the requisites which must be fulfilled when preparing for degumming:—

1. That the fibres remain motionless, in order that they may not be exposed to the least violence during the period in which they are immersed in the hot solution of soap.

2. That the inequalities of heating be avoided by causing the bath to circulate at a moderate speed from the receiver in which the silk is placed to that in which the heating should operate.

3. That it be possible at any moment to take out the silk that needs a degumming of less duration.

We think these conditions can be fulfilled by adopting the methods that were employed in the mechanical

¹ Revue des matières colorantes, 1905, page 58.

dyeing of threads, according to the methods introduced by Obermayer into the Wool industry. As we know, the characteristic of this Inventor's apparatus is the possibility of preventing, during the dyeing operations, the felting of the threads of wool, which is caused by the same physical actions to which we attribute the variable formation of fiocchetti.

It is understood that, for the degumming of the silk, those methods will be preferred which allow of the inversion of the soap bath in such a manner as obliges it to filter through from high to low, and *vice versa*, to the silk, which is kept between two discs full, top and bottom, with small holes to assure the uniformity of the degumming or boiling-off.

The condition of keeping the thread motionless during the action of the soap bath—which from our experience is shown to be the condition essentially favourable for preventing the formation of fibrillæ—is not easy to apply industrially, when one wishes to accumulate a thick bed of the skeins of silk in the apparatus for circulating, because the sericin that covers the raw-silks, when softened by heating, gums the threads one to the other, forming an impermeable stratum, which hinders the movement of the soap solution. The circulating apparatus can, therefore, only be employed for the degumming when the sericin left by the fibre in the first bath of soap has been eliminated from the silk. That fact does not take away from the value of the caution suggested by us, since the danger of the split-up or divided fibrillæ is made manifest especially in the moment in which the last remains of sericin must be eliminated in order to give the thread the greatest brightness of which it is capable. For this reason the silks should be at first partly degummed on sticks, as is usually the case with souples, before placing them in the circulating apparatus.

Among the various methods thought of, the following seems to us preferable, as it offers no difficulty with regard to construction.

In the Plate 13, sketched below, A represents the cylinder in which the silk which is to be degummed is placed between two discs full of holes; B is the reservoir for the solution of soap, heated by the coal S; P is the rotary pump which serves for the circulation of the bath.

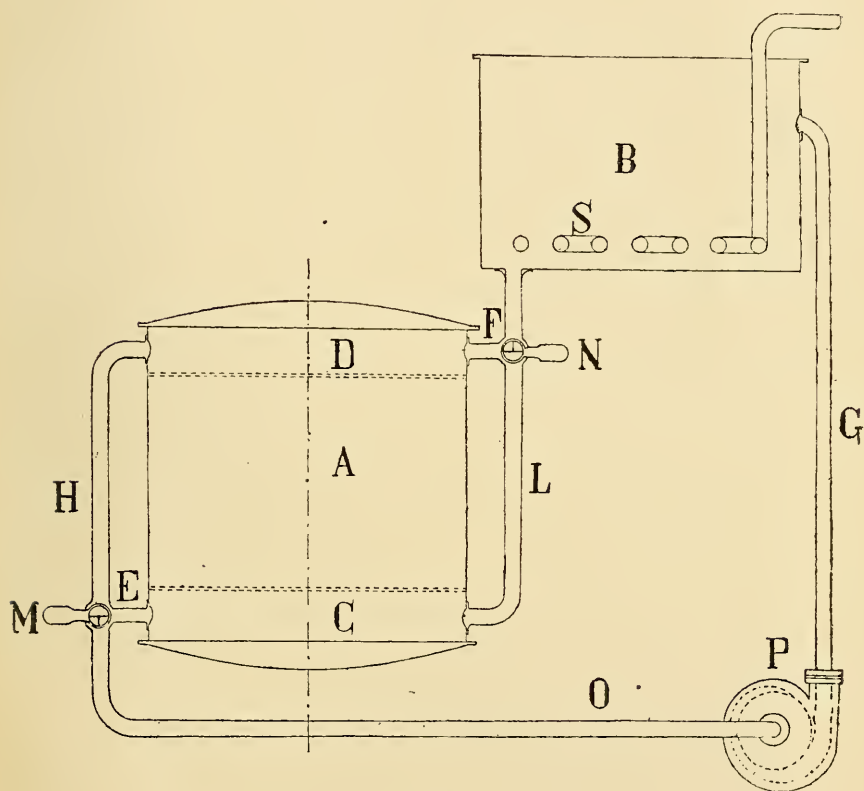


PLATE 13.

This latter sends the boiling solution of soap from the reservoir B by the pipe L across to the silk in the chamber D, and hence by the tube H O, to return it by the tube G, and so on to the reservoir B. By reversing

valves M and N the pump sends the solution of soap by the tube F, and, the communication E being open, the bath arrives in the chamber D, from which, passing through the silk, it comes into the chamber C, and by the tubes O G returns to the reservoir B.

It is needless to point out that by obliging the soap solution to pass through the silk alternately from high to low, and *vice versa*, the danger of unequal heating is excluded, and also that it is possible to boil-off the gum in a shorter space of time. In fact, an apparatus constructed according to this principle for use in the laboratory has allowed us to obtain the degumming of a specimen of silk that seemed specially disposed to splitting or dividing by the ordinary methods, without it showing, after dyeing, a perceptible number of balls, slubs, or specks.

The utility of the innovation proposed by us is confirmed by the fact that the system of making the soap solution circulate by means of a pump, and by the help of pressure exercised by vapour, has already been advantageously applied in some establishments, and for that reason we maintain that there should be no opposition to the abandonment of the system pursued up to the present date.

CONCLUSION.

We flatter ourselves that the researches we have brought together, and the considerations shown with regard to the causes of the formation of balls, slubs, or specks, called *flocchetti*, on dyed silks, will serve to convince—

1. That all silk fibres, in greater or less proportion, are subject to splitting or dividing, and that the inconvenience resulting from the formation of *flocchetti* is not peculiar to silks of Italian culture alone.

2. That it is the duty of the silkworm-rearer to keep account in his selections of the structure of the silk fibre, and to eliminate those races in which the silk is seen to be unusually streaked and subject to splitting or dividing.

3. That the Manufacturers should ascertain by suitable tests, before buying, if the silk chosen is adapted to the making of the article that they propose to produce with regard to the defects that the splitting or dividing up of the fibre may give rise to.

4. That to the Dyer belongs the obligation of proportioning to the various resistances of the fibre the treatment this latter ought to undergo in degumming and dyeing, and of employing the methods shown by us to give their maximum brightness to the threads and the tissues, without causing the divided fibrillæ of the brin.



EXPLANATION OF ITALIAN AND FRENCH TERMS USED.

- Fiocchetti* Minute excrescences, balls, "slubs" or specks, consisting of fibrillæ or sfaldature, on the silk fibre or fabric.
- I nodi, le anse, arciffamenti.* "Slubs" or "foul" occurring on the bave of raw-silk; in French the small ones are called "duvet" and the larger ones "bouchons"; they are not of the nature of "fiocchetti," but are excrescences of imperfect cocoon-reeling.
- Sericina* Sericin, silk gum, or grès.
- Fibroina* Fibroin, silk fibre.
- Filiera* The fibre-forming tube and exit orifice of the silkworm.
- Filière* The pierced guide, often of agate, through which the cocoon threads or baves pass from the bassine to the reel to form the hanks of raw-silk.
- Seritteri* The chambers or cavities in the silkworm containing the silk in the viscous state, and the canals from them to the filieras.
- Brin* The French term for each of the two single fibres, which are seriposited simultaneously by the silkworm.
- Bave* The reelable cocoon-thread, consisting of the two brins; a bave, therefore, is a double brin.
- Decorticazione* Removal of the bark or gum.
- Striature* Striations, appearances of fibrillæ, ribbiness, channelling.
- Reddito* Rendement, yield.
- Fibrillæ* The divided microscopic fibrets or sfaldature of the brin.
- Sfaldarsi* Splitting or dividing, to exfoliate, to divide, to fall into splinters or fibrillæ.
- Sfaldatura-e* The split-up or divided fibrillæ.
- Sfaldabilita* Liability to divide into fibrillæ.
- Sfaldabili* Divisible into fibrillæ.
- Sfilacciarsi* Frayed or ravelled.
- Saltuarita* Irregularity of recurrence.
- Attaviche* Atavism; recurrence of disease or peculiarities of more or less remote ancestry or breed.
- Flaccidezza* Flaccidity; flabbiness; relaxed fibre; want of tension.
- Sviluppata* Developed, unfolded.
- Copri-oggetti* A two-plate machine appliance.
- Vacuoli* Vacuoles or cavities in the protoplasm.
- Provisione* Apparatus.

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